# Weeds

*Journal of the Association of Regional Weed Control Conferences*

VOLUME I
OCTOBER 1951
NUMBER 1

*Sponsored by*
The Association of Regional Weed Control Conferences

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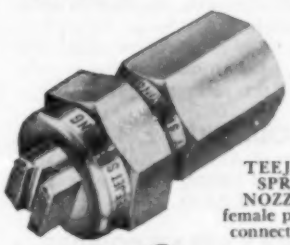

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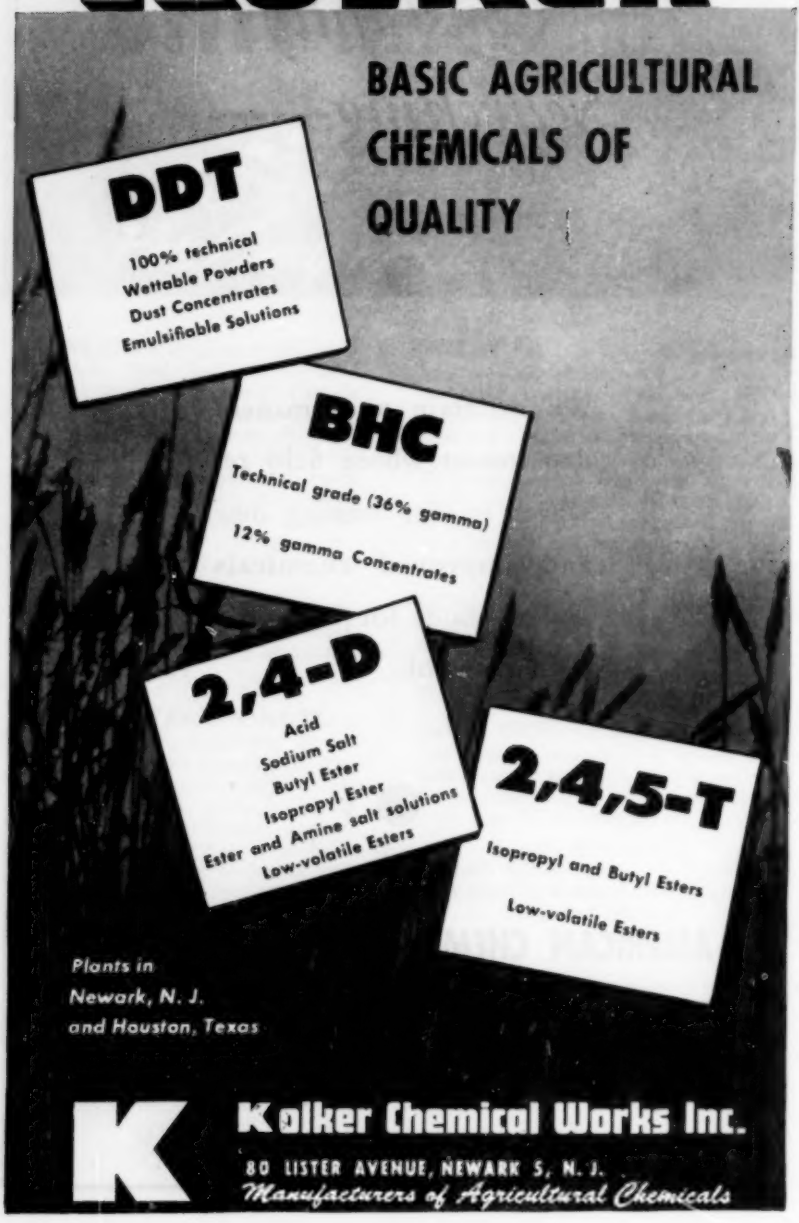


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# *Weeds*

JOURNAL OF THE ASSOCIATION OF REGIONAL WEED CONTROL CONFERENCES.

VOLUME I | OCTOBER 1951 | NUMBER 1

## "Weeds" Has Germinated

MANY PERSONS have worked long hours at no pay to make possible this first issue and to insure at least three more. The development and ultimate worth of "Weeds", however, depends on you, Mr. Reader. Just as germinated seeds need fertilizer, water, sunlight, and painstaking care to insure sturdy plants and a good harvest, so does "Weeds" need support, guidance, reprimand and tolerance before it can evolve into the useful place it deserves in the field of agricultural publications. If you do not care what some distant "they" do with "Weeds", it will surely wither and die.

What would you like to find in "Weeds"? Some of our subscribers primarily prefer highly technical research papers, others desire summaries of researches on a given broad topic. Some would like news of weed developments in extension, education and regulation, whereas others think more information on the chemical supply situation, sources of new herbicides, and industrial developments would be of most value. We are attempting to have something along each of these lines in each issue. There will be no attempt to restrict space for any of these several topics. But what we print depends on the copy we receive (provided it meets approval of the standards set up by the editorial board). The amount of material appearing on any topic in each issue will be a good index of current interest in that topic. Undoubtedly certain numbers will have much space on regulatory aspects if important new laws are proposed or passed, and likewise, some issues may have considerable about a new herbicide that happens to perform well in a number of experiments.

It is hoped that we will soon have a sizeable "letters from readers" section where we can air the views of our subscribers on everything pertaining to "Weeds" and weeds.

# Where Do We Go From Here?

C. J. WILLARD,[1]
*Ohio State University, Columbus, Ohio*

ONE OF the important steps in the maturing of a field of science is the establishment of a journal devoted to that field. A centralized means of publication is almost a necessity if a given branch of knowledge is to progress. "Weeds" is an attempt to fulfill that requirement for the science and art of weed control. If need is a measure of probable success, the success of "Weeds" is assured. Weed control literature has been published in every kind of journal — agronomic, horticultural, engineering, chemical, botanical, — and farm papers of all types, to make only a beginning.

Weed control papers will continue to appear in these publications, because of their vital importance to all these groups, but a journal devoted to weed investigations should be a unifying and vitalizing factor in weed work.

One could wish our science had a clear simple name, without the circumlocution "Weed control". Already our field is greater than "weed control", unless "weeds" are defined much more widely than is usually done. The field is "undesirable plant control" and includes the control of trees, stump sprouts, brush, and volunteer crops, none of which would usually be called "weeds".

What next? Our science has been mushrooming. Three full time weed men in 1934 and not too many part-time ones. Now, forty-six State Agricultural Experiment Stations have active weed research projects. The establishment of a Division of Weed Investigations indicates a recognition of this science by the U. S. Department of Agriculture. The expansion has been even greater in the chemical industry.

However, we still have a long way to go. Nothing is clearer than that *each* species, *each* variety in many instances, reacts differently to *each* herbicide, so that nothing short of testing *each* important herbicide on *each* important plant (weed or crop) using a wide range of dates, rates, formulations, and perhaps methods of application will give any real idea of how to use it.

How far we are from this ideal is shown by our basic ignorance about even 2,4-D, the catalyst which generated the recent and continuing explosive reaction concerning plant control by chemical means. Consider, for example, the tables of susceptibility to 2,4-D, which we began preparing in 1945, and which are only slightly more accurate today. Of the newer herbicides which are pouring from our laboratories of organic chemistry, we know much less. Fortunately we can use herbicides in situations of demonstrated value without knowing all about them, but we get into myriad difficulties.

I recently talked to a man who had done some very fine work on the physiology of a herbicide applied to the soil and absorbed by

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the plant. I asked what soil type he had worked with. He did not know – not even whether it was sandy or clay. Yet any herbicide applied to the soil is inevitably affected by the almost infinitely complex properties of the soil itself – for example, its permeability, pH, chemical composition, colloid content, and biological population. There is almost infinite room for studies of relationships between these properties and the reactions of herbicides.

We must know how the external environment affects each plant in its reaction to each important herbicide. Since the beginning, we have recognized that such matters as temperature, humidity, and physiological condition of the plant affected results. Yet where are quantitative studies of the effects of these factors with specific herbicides on specific plants? These comments are not intended to criticize anyone for what has not been done. Every worker has seen more problems than ten men could carry out and I believe that, by and large, the decisions as to what problems were most important to work on at the time have been excellent. I am merely calling attention to the vast backlog of "unfinished business" we have yet before us.

We must know the life histories of the plants with which we are working. An amusing but serious problem has arisen for many of us who have tried to study annual weeds and found that when one wanted them to grow, we could not get the seeds to germinate! Despite the work which has been done on dormancy of seeds, it must be greatly extended.

The amount of reserve foods stored in perennials is almost as important in determining the effects of herbicides as in determining the results of cultural practices. We must extend the knowledge of food reserves in the plants to all important perennial weeds, including woody species.

Perhaps the most universally important field in plant control is the control of brush and woody plants. There is no section of the country that does not produce unwanted brush, and in the past its control has been a matter of main strength and awkwardness, with almost complete frustration in many instances. Ask the men who have carried tons of salt to eradicate common barberries in isolated places! Now we are seeing marvelous results from the newer herbicides, and the surface is hardly scratched. Range lands, pastures, stump sprouts, fence lines, electric transmission lines, weed trees and plants in forests, poison ivy; the tens of millions of acres and infinite human effort potentially savable through woody plant control stretches the imagination.

A field requiring far more study is soil sterilization – the prevention of all plant growth. The old-timers can do a fair job with sodium chlorate and sodium arsenite, singly or combined, but surely there must be other and, for at least some situations, better methods. The writer knows of no systematic project in this field in Eastern United States, yet it is one which gives rise to almost as many questions as any other field.

We have given far too little attention to methods of applying

herbicides, chiefly because progress in this field is slow and expensive. Its importance is illustrated by the fact that the extensive use of 2,4-D dates from the development of the low-volume, low-pressure sprayers. We need far more study of spraying weeds while shielding the crops, in which promising starts have been made. Several millions of acres are sprayed by airplane each year, yet this method is only in its infancy.

Despite all of the current and justified furor over chemical weed control, cultural methods are still basic to controlling weeds in crops, largely because many of the operations must be carried out whether weeds are present or not. We knew much, though by no means enough, about cultural controls before 1945. What is particularly needed now is to work out the most economical combinations of chemical and cultural controls for each weed in each crop under the widely varied conditions represented in this country – no small order! Other cultural practices besides cultivation may make chemicals more effective – witness hill planting of cotton to be treated with di-nitros. Research on cultural methods of control is more difficult and expensive than with herbicidal controls, but it must not be neglected.

Workers in the plant control field must become better chemists. We can, of course, put on Herbicide 717 or Weedkiller 491 without knowing more about them than whether they clog the nozzles. But the more we understand the chemical relationships of the materials we are using the more intelligent and satisfactory job we can do. Obviously, however, this is a place for teamwork. Workers in the field will always depend for the most part on the trained chemist for materials and formulations.

It is popular just now to say that we must do more "fundamental" work in weed control. No one will dispute this, but how shall we define "fundamental"? Surely studies on the relation of chemical configuration to phytotoxicity would be in this category. Why, for example, does adding a chlorine atom in the "5" position to 2,4-D make it much more toxic to certain woody plants, while adding a chlorine atom in the "6" position actually reduces its general toxicity? Unquestionably the organic chemist searching for other possible herbicides could use this information, and it is of vital importance in understanding how herbicides act.

But, actually, is that information any more fundamental than an accurate study of the relation between stage of growth and effect of 2,4-D, for example? Until this information was accurately obtained for cereals, many acres were damaged by treating at sensitive stages, and safe recommendations could not be made. The data on stage of treatment were, perhaps, easier to get, but they are essential to our knowledge of the behavior of 2,4-D.

A wise liberal clergyman once said in connection with questions of orthodoxy, "Orthodoxy is my doxy, heterodoxy is your doxy". So, one suspects, in many cases "Fundamental research is what I am doing, superficial or "applied" research is what you are doing". In all directions we need more complete and extensive information,

obtained by experiments so broad and conducted by such superior techniques that the answers, when obtained, will not be successfully contradicated by the next set of experiments. Experiments of this kind on any plant-herbicide-environment relation will be of lasting value, whether designated "fundamental" or not.

Even the so-called "routine" testing of new herbicides that "anybody can do" is routine only if just "anybody" is left to do it. If done by those who combine keen observation and imagination such testing can be one of the most fruitful sources of fundamental leads and problem. The techniques of such testing require far more study than it has so far been possible to give them. Perhaps they cannot be improved, but in view of the specificity of herbicidal effects, present trials resemble nothing so much as using a 1-inch-mesh net to catch minnows. There must be a lot that get away!

All of us in weed control have a job of education; informing the public, legislators, and administrators, of what has been done and the future possibilities of modern plant control, and especially the need for greatly expanded personnel for both research and extension. Even now, less than half the corn belt states have weed control specialists in their Extension Services, despite the overwhelming value and importance to the public of plant control.

Today the chemical companies do a very important share, probably more than half, of weed control research. This is all to the good. The production, screening, and initial testing of new herbicides should be done largely by the chemical companies which profit by their sale. More and more, research expenditures are recognized as essential to continuing programs. The writer recently saw an evaluation of the stock of chemical companies as investments. One of the suggested measures of the relative desirability of investment in a company was the proportion of gross income used for research.

But there should be a balance between company research, and public research. The companies themselves have subsidized much public research, with no strings attached, but more tax money should go into it. Like the companies, the sound progressiveness of a state or nation may be rightly judged in part by the proportion of its income it puts into research.

Where do we go from here? Everywhere. For a long time it will be difficult, because of pressures from all sides, to avoid "riding off madly in all directions". But, finally, surely, we will build a science and art which will go far to relieve the primeval curse placed on Adam when he was cast out of the Garden of Eden.

## Regulatory Phase of Weed Control

By WALTER S. BALL, *Chief, Bureau of Rodent and Weed Control and Seed Inspection, California Department of Agriculture*

A successful weed control program, whether it be Federal, State or County is involved with research, education and regulation. Had laws been enacted and properly enforced in all states thirty or forty years ago to prohibit the introduction of noxious weeds the weed problems of today would not be so serious.

Laws were enacted in some states even in the last century, but unfortunately, like many of the laws passed by state legislatures, they were not properly enforced. In many states poor enforcement is due to inadequate appropriations. This situation is improving, however, and although the regulatory programs differ in organization and enforcement, weed control is being regulated in many more states today than ten or fifteen years ago.

One of the most important phases of weed control is prevention of the introduction and the spread of weeds. This is a most important part of regulatory work and perhaps the one of which agriculture generally is least aware. The introduction and establishment of a new weed in a community, if found to be a serious pest to agriculture, generally brings a request for governmental assistance. Adequate inspection might have prevented this introduction.

Seed for planting purposes, grain movement, screenings and cleanings, have proved to be the best sources of introduction. Hay, straw, natural manure and some other agricultural products move weed seed from state to state, county to county, and farm to farm. Well known examples of this movement, even internationally, have been the introduction of bindweed, camelthorn, hoary cress, Russian knapweed, Russian thistle and others. True, there are many natural means through which weed seed moves, but not the great distances in most cases as brought about by man or animals.

The movement of crop seed screenings is another important means of disseminating weed seed, for in most cases the screenings are weed seed and dirt.

California has enacted a provision pertaining to seed screenings and cleanings. In part it is as follows:

"It is unlawful to move any seed screenings or cleanings from crop seed from the place they may be unless they first shall have been inspected by the Commissioner (County Agricultural Commissioner) and found to be free from the seed of any pest or unless they have been processed by grinding, or otherwise to render the seed of any pest incapable of reproduction....." Provisions are made under regulation for movement to processing plants. The various methods of processing are outlined, but must be approved by the enforcement officer. The regulation of screenings and cleanings, although not satisfactory in every respect, is responsible for the processing of tons of screenings that otherwise would find their way back to the farm. Regulation of screenings is important in any general weed

control program as many new infestations of weeds are traceable to this source.

The North Central Weed Control Conference took action through their regulation committee relative to the movement of weed seed infested materials. The committee reported in part as follows:

"Great strides have been made in the past in the enactment of strict state seed laws and a Federal Seed Law to govern the sale of agricultural seeds, while on the other hand weed seeds are being spread through these other avenues with very little restriction and still it is obvious that the average farmer buys considerable more feed grain than seed.

This Committee wishes to make the following recommendations:

(1) That further study be made as to the advisability of a federal law governing interstate movement of weed infested materials

(2) That the enforcement agencies of the states concerned cooperate to the best of their ability in bringing about supervision of the movement of weed infested materials, until such time as proper legislation is enacted for regulation.

(3) To regulate the movement in interstate and intrastate commerce of any feed, grain, seed or grain screenings, forage, bedding, packing material or other material containing live noxious weed seeds, unless stated on the label or the invoice that the shipment is intended for processing to remove or destroy the viability of the noxious weed seeds present, and that the material complies with the laws of the state into which it is to be transported."

Nebraska has taken the lead in regulating the movement of Transient Custom Combines to prevent the spread and establishment of new weed pests. This problem is equally important in all other states where custom combines are operating and in the large grain growing areas it is definitely an interstate problem.

Should a serious noxious weed become established and prove to be a potential hazard to agriculture, governmental agencies are often requested to aid in control and eradication. Regulations are then necessary to carry out the provisions of the act where state legislatures appropriate funds. Under California law abatement proceedings are provided to force those failing to cooperate in a program to comply. Abatement procedure may be used in county programs where a specific program is in operation.

Many states provide for the formation of weed districts, authorizing the county weed supervisor of the district to enforce the regulations pertaining to the program.

Weed control is becoming more and more complex, with the introduction of complex chemicals for weed control and improved methods of application. Where high concentrations and low volumes are recommended serious problems may arise.

Although research agencies provided considerable warning and caution as to the use of the new materials, unfortunately, some of

the applicators did not heed such warnings and applied the materials in such a manner that damage was caused by drift in a number of instances.

Damage suits have been filed and quite naturally state legislatures have been requested to enact laws controlling the use of these injurious materials. Arkansas, California, Louisiana and Texas were the first states to legislate toward control.

The action taken by the California legislature is found in Section 1066.7 of the Agricultural Code which provides that it is unlawful to use any form of 2,4–D or other herbicide, which after hearing, the Director finds and determines to be injurious to crops except as provided in this section, and in the rules and regulations of the Director of Agriculture. The section further provides that the Director, after investigation and hearing, shall adopt rules and regulations governing the use of 2,4–D and other herbicides, which he finds and determines to be injurious to the crops being grown in any area of the State.

In part the regulations adopted on "Injurious herbicides" are:

"The Director finds and determines that herbicidal preparations containing 2,4–dichlorophenoxyacetic acid (2,4–D), 2,4,5–trichlorophenoxyacetic acid (2,4,5–T) or 2–methyl–4–chlorophenoxyacetic acid (MCP), or any compound thereof, hereinafter referred to as "Injurious Herbicides", are injurious to certain crops grown in various areas of the State, hereinafter referred to as "susceptible crops", to wit: grapes; cotton; beans; peas; cowpeas, and other annual legumes; melons; cucumbers and other cucurbits; tomatoes, peppers and eggplants; lettuce and other annual garden vegetables; zinnias and other annual flowering ornamental plants; and many other plants and crops, particularly in the seedling stage and during periods of active growth. . . ."

"The Director finds that risk of injury to extensive plantings of susceptible crops is likely to attend the use of injurious herbicides within the following described areas, hereinafter referred to as "hazardous areas".

Hazardous areas throughout the state are described by legal boundaries. Permits are issued which prescribe time and conditions for use of injurious herbicides. At the same time the action taken relative to injurious materials, amendments were added to the pest control operators law. Regulating the application of weed control materials through the pest control operator has not only reduced crop damage, but has resulted in obtaining the cooperation of those operators who plan to remain in this business.

In the field of herbicides, new developments are being made everyday – most of which are beneficial to agriculture. The necessity for regulation in this field is being considered by many states. In some cases the laws that have been passed, or are being urged upon the state legislatures are very strict and in some states may be more harmful than beneficial. Other states which have been too lax in passing legislation may suffer from such neglect and carelessness.

Those states that have enacted legislation regulating herbicides

and agricultural chemicals are rapidly realizing the necessity for equipment to be used in the application of these materials.

The introduction of weeds through seed, grain, screenings, other agricultural materials and equipment continues to play a very important part in weed control programs, but is given little attention in most of the states. Regulations to prevent introduction and spread of weeds by these sources will save agriculture millions of dollars.

Harvesting equipment likewise moves weed seed into many clean areas, and regulation of harvester movement is badly needed.

Abatement provisions are very important to properly carry out a weed control program. Comparatively few states have such provisions, or if they do have they are unable to enforce them.

The new developments in agricultural chemicals have brought about new regulations. Several states either have laws or are considering legislation regulating injurious chemicals.

If susceptible crops are to be protected near the areas of weed control operations control of application and pest control operators is very important.

There are other regulations pertaining to weed control but those discussed are considered important and there is need for further education and regulation.

Through research weed control has progressed very rapidly, and education has been unable to keep abreast of the new developments. Regulatory work, likewise has attempted to keep abreast of the rapid growth in weed control. Regulations have always been necessary in these programs and careful consideration should be given new legislation requested to keep these developments advancing without impeding progress.

# Control of Roadside Weeds and Brush

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THE CONTROL of roadside weeds and brush has always been a major problem of roadside construction and maintenance engineers. People charged with the responsibility of keeping our highways, county, trunk and local roads free of weeds and brush have heretofore found the control of unsightly weeds and brush a major and laborious problem and expense. For the control of many annuals such as hemp, giant ragweed, small ragweed, daisy fleabane, etc., a very thorough, systematic mowing program, coupled with the establishment of a heavy grass cover has in many instances sufficed to keep weed growth down to a minimum. However, for the control of such roadside weeds as Canada thistle, perennial sow thistle, poison ivy, etc., as well as for the control of all types of brushy growth, the mere mowing and laborious cutting of such plants has not resulted in eradication. The mowing of perennial weeds and brush is like "picking apples off a tree" – such picking does not kill the tree. Furthermore, programs of control involving brush have had to be repeated every two or three years at terrific expense to the tax payer. Laborious mowing and hand cutting is followed quickly by regrowth, which in a year or so is as bad or worse as the original stand which was removed.

The advent of 2,4-D late in 1944 and the appearance on the market lately of 2,4,5-T have opened up a new era for weed and brush control for the highway and roadside maintenance engineer.

A well-sloped, well-grassed roadside shou'der and right-of-way is the fond dream of every maintenance engineer. A good deal of the change in the last few years, from unsightly weed and brush covered roadsides, to grassy roadsides, has been the result of chemical weed control practiced by alert highway workers, county boards of supervisors, weed commissioners, farmers, and custom sprayer operators. Through the use of chemicals it has finally become possible to eliminate most of these unsightly weeds and brush much more rapidly, completely, and cheaply than ever before.

But lest anyone jump to conclusions that in the 2,4-D and 2,4,5-T compounds we have "perfect weed killers" which will make the job of weed control along all our roads a very easy and effective task – we must remember that such weeds as squirrel tail grass, downy brome grass, quack grass, Johnson grass, etc., which are grassy weeds, are not injured by these weed-killing chemicals. We must also remember that such plants as black nightshade, white cockle, wild perennial ground cherries, devil's shoestring, etc., which are primarily broad-leaved weeds, are not too easily injured by the use of 2,4-D and 2,4,5-T. In all roadside spraying the danger of spray fumes and spray drift is of great importance. So while these compounds have gone a long way toward making our roadside weed and brush control problem easier, they are by no means the complete remedy to

all of our ills. Many other chemicals in addition to 2,4-D and 2,4,5-T have useful application in many instances.

It was not long after the advent of 2,4-D that farmers, county boards of supervisors, weed commissioners and custom sprayer operators found that certain plants were not too readily injured by these materials. However, with the advent of 2,4,5-T the number of perennial weeds and brushy plants that had shown resistance to 2,4-D gradually diminshed. It was not long until spraying along the roadsides was also implemented by spraying along railroad right of ways, under communication and power lines, etc. Many of the telephone companies, as well as the utility companies, have also begun extensive spraying programs, which will and have already reflected in much better service to the consumers of their services.

We might examine the merits of roadside and utility line spraying and ask ourselves this question – "What do we expect to get out of such roadside and utility line spraying programs?" The following points should be kept in mind.

### ERADICATION OF NOXIOUS WEEDS

There are many different noxious weeds growing on our roadsides. The weed laws of the various states aimed at the destruction of noxious weeds, most generally make some provision for the eradication of such roadside weeds. When such weeds are perennials, it is a waste of time to depend upon mowing practices to eradicate them. Furthermore, such practices as summer fallowing and smother crops cannot be used in such areas. If the weed infestations are extensive, probably blanket spray applications are necessary; that is, entire roadsides must be sprayed in order to control such noxious weeds. If, however, the patches are located in small areas, it may be possible that spot spraying can be done. Very few roadsides are completely free of noxious weeds. Everyone is agreed that the elimination of noxious weeds will be of benefit to everyone concerned, primarily to farmers in the agricultural areas. Weeds do not stop at fence lines. Roadsides must be cleaned up if you expect farmers to clean up their property. Furthermore, roadsides serve as excellent demonstration areas for the eradication of noxious weeds. Usually blanket application is necessary because many noxious weeds are very common along our county, trunk and local roads. Furthermore, spot spraying is often too expensive because the spots are too numerous to ferret out individually. However, once the majority of the weeds have been eradicated, spot spraying may then come in as a follow-up, a clean-up, or as a policing job. Some roadsides which have been blanket sprayed for a year or so are already being spot sprayed in this manner.

### EASIER MAINTENANCE

From the standpoint of maintenance, roadside spraying is definitely justified. Once the weeds and brush are eliminated from an area, the prevailing grasses are given a chance to establish themselves and this in itself is a long step in a highway maintenance program. As

mentioned previously, a well-grassed, well-sloped shoulder and right-of-way is the fond hope and dream of every maintenance engineer. Unfortunately not all of our roadsides were originally built that way. The bank may be too steeply sloped, or, full of rocks and debris, or may be somewhat eroded, and inaccessible to good mowing equipment. A boom from a sprayer can very often be hung over such a roadside and relatively good results accomplished efficiently and quickly. Roadsides which are clean, free of weeds and brush, are also easier to maintain from the standpoint of snow removal. They are also less inviting to indiscriminate dumping of rubbish. Weed and brush free roadsides allow free air circulation and highway shoulders, right-of-ways, and roadbeds dry off more quickly and completely after snow or rain.

### SPRAYING IS MORE PERMANENT CONTROL

Many roadsides are covered by volunteer brush. Such brush even though laboriously cut once every two to three years at great expense to the responsible agency, causes traffic hazards in the way of obscured vision, in the way of adding to the hazards of drifting snow, and from the standpoint of slower drying off of the roads and roadbeds. Hand removal of established brush is a time consuming, laborious process. However, if hand removal were the end of the problem, it would be well worth-while. The difficulty is, it isn't. Cut-over brush merely sends up more shoots the following year and makes the problem infinitely worse than it was before. Getting rid of brush by means of chemicals not only is cheaper, but inroads are made on the perennial plants so that year after year when the spraying is done, there will be fewer and fewer of these brushy plants to eliminate. Once such brushy plants as well as weeds have been eliminated, the prevailing grasses are given a better chance to establish themselves and this in itself is a good deterrent to weed and brush establishment. It is very seldom that either weeds or brush can secure and maintain an extensive foothold in areas which are inherently covered with a good heavy, thrifty sod of prevailing adapted grasses.

### ELIMINATES TRAFFIC HAZARDS

From the standpoint of safety, roadside spraying will help eliminate brushy intersections or intersections surrounded by heavy, tall weed and brush growth. There are very few people in the midwestern area of our land who do not at one time or another use highways other than primary highways. One needs only to take a trip of 5 to 10 miles over almost any country road and find roadsides where vision is obscured, especially at intersections, at field entrances, and at farmsteads. Roadside removal of weeds and brush will enhance the safety factor by eliminating this high growing vegetation in favor of lower growing grassy plants. The life that is saved may be your own.

### ELIMINATES HEALTH HAZARDS

Many of our roadsides are infested with such hay fever producing plants as small ragweed and giant ragweed, as well as others, and with such definitely poisonous plants as poison ivy. These plants are a definite hazard both to the adjacent farmer, to the county maintenance worker, and to the occasional user of such roads, be he urban or rural. Only persons who suffer from the effects of pollen allergies or poison ivy can appreciate the benefits that would be derived from the elimination of these plants. Furthermore, if all of us were good stewards of the lands under our jurisdiction, to the extent where we controlled poison ivy and ragweed, 10 per cent of our people would be infinitely happier because of such action. While it is too far fetched to state that the removal of ragweed from the roadsides would result in the elimination of hay fever, it is certainly a desirable step in the right direction. In some of the counties where blanket spraying has been practiced for a year or two in succession, worth-while results have already been accomplished and many people have remarked about the greater absence of both poison ivy and ragweed along such roadsides. Any step we can take in the elimination of such unwanted plants as poison ivy and ragweed should be encouraged. The loss of time, the human suffering, that is endured because of these plants, is a well known factor and can be ascertained from any hospital or physician. Many county workers consistently lose time from their jobs because of poison ivy. Lost time and lost working efficiency and untold suffering take a tremendous toll every year.

### IMPROVES UTILITY SERVICES

The utility services such as telephone and power companies have a tremendous interest in the control of roadside brush. Theirs has been a thankless job of cleaning out under such utility lines and in two or three years facing the necessity of going back and doing the job all over again. This costs money and hard labor. Control of such unwanted vegetation which seriously interferes with power and telephone service by shorting lines can be immeasurably improved by a good spraying program. Rural telephone service, especially such service as is carried on rather short poles, can be improved immeasurably. There are instances on record where the number of dead lines following a storm have been reduced from 8 or 9 after each storm to none after a good spraying program was initiated. This is because sprouts or breaking branches have interfered with the signal and power transmissions. Subscribers of these services depend upon services at all times. It must be reliable – most of all, reliable in times of emergency. Spraying for the control of unsightly brush can help make such services more reliable.

### IMPROVES BEAUTY

From the standpoint of downright beauty, there is really nothing that compares with a good grass cover along our roadsides. A heavy grass cover prevents weed encroachment, cuts maintenance costs, and

helps prevent erosion. Selective chemicals will kill only broad-leaved plants. If you can get rid of the weed competition, many of the adapted grasses will be quick to establish themselves on such cleared areas. The only materials extensively available and cheap enough to practice blanket on roadsides are, of course, the 2,4-D and 2,4,5-T compounds. These used according to recommendations will not injure established grasses. By getting rid of the weed competition, these chemicals aid in the establishment of grasses. Such grass does not interfere with vision, drifting snow, or drying off of the roads. It is well agreed by county weed commissioners, boards of supervisors, and custom sprayer operators that fine stands of grass have come to replace unwanted ugly weeds along miles of our primary and secondary road system through a good spraying program.

### SPRAYING CHEAPER AND FASTER THAN HAND REMOVAL

Weed and brush removal by means of chemicals is infinitely cheaper than by means of hand labor. It is much more permanent in that the roots of many unwanted weeds and brush are gradually destroyed and this is especially true after repeated treatment. The decreasing cost of such roadside and utility line spraying year by year is mute evidence of the fact that such programs are worthwhile from the long range standpoint. In one instance the original cost of spraying a mile under a utility line where the vegetation was fairly heavy was $35.00. The second year a re-spraying job cost $24.00 for that same mile. The third year with most of the weeds and brush gone the touch-up job required $6.00 per mile. Hand labor would have required all the way from $200 to $400 per mile, once every second or third year. Chemicals make maintenance more easily available where the terrain of the ground is so rugged that mowing cannot be done. Spraying is faster than mowing which adds another desirable aspect to roadside spraying. While the sprayer probably will never completely replace the mower, it is an aid to good mowing programs. Because many tall growing weeds and brush are replaced by lower growing, more aggressive, more fibrous rooted grasses, roadside spraying is an aid against soil erosion. At the same time the lower growing grasses will make for improved vision along our county, trunk, local, and primary roads. From the standpoint of snow removal, from the standpoint of better air circulation, the control of roadside weeds and brush is justified.

### OBSTACLES CAN BE OVERCOME BY JUDICIOUS FORETHOUGHT

We must not be misled into thinking, however, that roadside spraying is all "pure gold". There are some very definite hazards connected with roadside spraying, which should be fully thought out in advance before extensive spraying programs are undertaken. In the first place, it is necessary to undertake a positive program and point out where such spraying will benefit the taxpayer, the populace as a whole, the user of the roads, be he rural or urban. In other words, an educational job must be done which will point out the benefits

of roadside spraying programs. The growth of roadside and utility line spraying alone in the last few years is mute evidence that such spraying pays benefits from the monetary standpoint. However, we must point out that it is more than dollars and cents which we expect to get out of such roadside spraying programs. The control of noxious weeds, the control of brush from the standpoint of maintenance, the control of tall growing weeds and brush from the standpoint of safety, the control of poisonous plants such as ragweed and poison ivy, the improvement of the rural telephone service, more reliable power delivery, the increasing beauty on our highways, all must be stressed in a good educational program. We must also adopt a compatible working relationship between all groups involved. We must remember that there are usually arguments on both sides of a problem. Not all people may share our views. We should be tolerant of their opinions. There may be a good reason for them. Good working relationships should exist with the groups and owners of the farm lands adjacent to which the spraying is to be done. Persons to be affected by such spraying procedures probably should be contacted before hand because very often there are certain trees, vines, or shrubs growing, which were planted by ancestors and which have a sentimental value. Nothing would be more irritating to the adjacent landowner than to have such valued and sentimental plants destroyed. Certainly there is no room for turning loose a group of inexperienced, untrained operators with such potent materials as 2,4-D and 2,4,5-T. Spraying should be done under close supervision with well trained operators, who are familiar with the weeds, the problems, and the dangers of spray fumes and spray drift. Application of these chemicals must be thorough. There is no room for a slovenly job. Instances where trees were sprayed only on one side have continued to serve as horrible examples of a job only half done. No one condones promiscuous spraying. Horse sense and common sense, in addition to the regular senses with which a man is endowed should be exercised by every custom sprayer operator and those in control of spraying programs. Competent supervisors are essential. We must remember that there is some beauty in massed flower vegetation along our highways. Many wild flowers are killed by indiscriminate spraying. It is not very often that tremendous flower populations are found in extremely weedy areas. Generally speaking, the most beautiful wild flower displays are found in areas where there is a relatively pure stand of grass. However, we must remember that wild flowers cannot "pack their old kit bag" and move on into other areas. When wild flower populations are heavy and extensive, spraying probably should not be done. On the other hand as we have mentioned before, it is very seldom that you find heavy wild flower populations in extremely weedy or brushy areas. Good judgment on the part of the operator can readily tell such areas and these should not be sprayed.

The elimination of game cover has very frequently been cited as a reason for discontinuing roadside spraying. Actually inumerable animals are killed, both on primary highways, and along county, trunk and local roads, by fast moving traffic. The more we can dis-

courage animals from frequenting such areas, the more game we will eventually conserve. Actually roadside spraying is a blessing in disguise. If the cover is not present along the roadside, such animals will gradually move into wildlife preserves, gullies, ravines, farm shelterbelts, and other thickets, and into our timbered and park lands where they will be much safer from fast moving traffic as well as poachers. A short airplane trip will quite soon convince almost anyone that the amount of land in road right-of-ways is quite small in comparison to the total amount of land. Good working relationships with adjacent farmers who control the majority of the land to encourage them to establish more wild life areas, is a step in the proper direction.

A fast developing program such as that encompassed by roadside and utility line spraying is bound to be misunderstood at its inception. A good positive approach to explain the meaning and the purposes of such a program is absolutely essential to its welfare. It must also be remembered that a roadside full of dead brush is not the most beautiful sight in the world. We must keep the ultimate vision in view. Eventually such dead brush will be eliminated by nature. Also, we can help dead brush elimination by helping crush down such dead vegetation with proper machinery. If this is done, grasses will heal the scars very rapidly and long brushy fencerows full of dead brush will not longer be common eyesores. Cooperation between utility line spraying and county and highway spraying is highly desirable. One concern could possibly do the spraying, the other could help in the removal of such dead material. We can overcome all of the hazards which have been mentioned. What we need most is to undertake a good positive educational program to show what the eventual benefits of roadside spraying will be. We need well trained, conscientious operators, who are conscientious of their job and completely informed as to the potency of the chemicals involved. If we believe that our wild flowers and game populations are in imminent danger of destruction through roadside spraying programs, then we should advocate the use of more city- and state-owned parks, game preserves, wildlife areas, etc. Wild flowers, which would seem to be in danger of elimination, could be transplanted by means of actual plants or seeds into parks, game preserves or other areas where they could grow and flourish unmolested. If such areas are made available, game will readily seek them out and inhabit them in preference to dusty, weedy, brush-infested roadsides. We could utilize a great many more extensive roadside parks. Many of the wild flowers which seem to be in danger of destruction could be transplanted into such roadside parks, game preserves, and even into the gardens around our own homes. More farm ponds (such as are forthcoming now on an increased basis) aided and abetted by good soil erosion practices as advocated by the Soil Conservation Service and the establishment of more chapter- or individual-farmer owned wildlife areas such as advocated by the Izaak Walton League are all commendable steps which will more than offset any damage to wild life which will be done by roadside spraying programs. The very fact is

that we are woefully short of wildlife preserves, game areas, state and city-owned parks, roadside parks, farm ponds, man-made lakes, wildlife areas, etc. A good roadside spraying program which will hasten the day when more such recreational and wildlife areas are available is certainly commendable. The country as a whole, rural and urban dweller alike, has much to gain from a good constructive well-rounded, well-founded roadside spraying program. Roadside spraying programs like the automobile and the airplane, are here to stay. It is up to us to utilize its benefits and limit its hazards. We have everything to gain and very little to lose in a well-planned, well-executed roadside spraying program.

# Determinations of the Effect of[1] Several Herbicides on Soil Microorganisms

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MILLIONS of acres in the United States are being chemically treated each year for the control of weeds. Weed investigators have generally accepted the fact that certain herbicides affect certain plants to a greater degree than others. Because of this, numerous chemicals are being used. Except for 2,4-D, there has been little work done on the bactericidal and bacteriostatic properties of the recent herbicidal compounds. It is the purpose of this paper to report a study of the influence that several recommended and experimental herbicides have on the microbial activity of the soil population and to establish the usefulness of a simple procedure outlined by Nelson (8) in making preliminary determinations of this type.

Investigators have studied the influence of 2,4-D on microorganic activity by several methods. Crafts (2), Hanks (5), Hamner, Moulton and Tukey (4), Taylor (12), Van Overbeek and Velez (13) report that 2,4-D is relatively non-toxic to most plants after periods ranging from two to seven weeks in most soils. This period may be prolonged in dry soils. Payne and Fults (9) reported that 0.075 pound of 2,4-D acid per acre when mixed with the soil was sufficient to depress nodulation of roots of common beans. They do not indicate whether this was due to the effect on the free bacteria, or the depressing effect of the 2,4-D on the bean plants. Lewis and Hamner (6) found no influence of 2,4-D on *Rhizobium leguminosarum* – even at high concentrations. This work was carried out by using seeded plates of bacteria and treating these plates by placing a filter paper disc dipped in 2,4-D over the media of the plate. Carlyle and Thorpe (1) studied the effect of 2,4-D on *Rhizobium leguminosarum, R. phaseoli, R. trifolii, R. lupini, R. japonicum,* and *R. meliloti,* using both live plant and plating methods. They concluded that the depressing effect on nitrogen fixing bacteria, if any, occurred as a result of the herbicidal response of the host plants; rather than the direct response of rhizobium living free in the soil. Martin (7) showed that low concentrations (10 ppm.) of 2,4-D did not inhibit soil organisms and fungi. Heavier concentrations inhibited some microorganisms but not others, and was more toxic under acid conditions than under alkaline conditions. Smith, Dawson, and Wenzel (10) concluded that 2,4-D at 1 ppm. to 100 ppm. had no significant effect on total plate counts of actinomyces, fungi, and protozoa in the silt loam soil used. Nitrite and nitrate formers, injured at 100 ppm. recovered in

[1]Journal Paper No. 264, of the South Dakota Agricultural Experiment Station. A portion of a thesis submitted as partial fulfillment for the requirements for M.S. degree. Complete copies are on file at the South Dakota State College Library.

[2]The author wishes to acknowledge the assistances and guidance of Dr. L. M. Stahler, USDA and Dr. W. W. Worzella, Head of Agronomy Department, South Dakota St. College given throughout this study.

10 to 14 days. Stevenson and Mitchell (11) reported that a fungus (*Pencillium* sp.) grew vigorously on 0.1 per cent 2,4-D in 0.5 per cent carbowax and potato dextrose agar at a pH of 5, 6, or 7, but was inhibited at a pH of 8. Culler, Weiser and Wetman (3) detected no physiological changes due to 2,4-D in cultures of several bacteria associated with food spoilage. Fungi treated were inhibited only at very high concentrations of 2,4-D – 10,000 ppm. or higher.

In general, information reported from the various investigators indicates that 2,4-D is relatively non-toxic to most microorganisms at low concentrations which would be about equal to the concentrations generally used in the field for weed control.

## MATERIALS AND METHODS

Eight herbicidal chemicals were studied in this investigation. They were an amine salt of 2,4-D at rates equivalent to one, two, three or four pounds per acre, 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) at rates of one, two, three, four, eight or 16 pounds per acre, sodium salt of PCP (pentachlorophenol) at two, four, eight or 16 pounds per acre, sodium salt of TCA (trichloroacetic acid) at 10, 50, 100 or 150 pounds per acre, IPC (isopropyl-N-phenylcarbamate) at four, eight, or 16 pounds per acre, E. H. No. 2 (dichloralurea) at two, four or eight pounds per acre, E. H. No. 1 (sodium 2,4-dichlorophenyl "cellosolve" sulphate) at one, two, four or eight pounds per acre, Endothal (disodium 3, 6-endoxohexahydrophthalate) at one, two, four or eight pounds per acre. All rates were calculated on an active ingredient basis.

The technique used in this study is a modification of the one described and used by Nelson (8). The surface six inches of Barnes silt loam, from a field of red clover, was used for all determinations. After air drying the soil and removing all large roots and stems the soil was ground to pass through a 20 mesh sieve. The pH of the thoroughly mixed soil was found to be 6.45 on a 1 to 5 water dilution basis. Using 100 grams of soil and four grams of dextrose per sample a high media level for microorganic activity was obtained. The samples were placed in 250 cc Erlenmeyer flasks and treated with the chemicals at the rates mentioned earlier in the paper. Sufficient water was added to each sample when treated to bring the moisture content of the soil to approximately 35 per cent by weight. Preliminary trials run on soil samples of various moisture content showed 35 per cent to be optimum for maximum microbial activity. The flasks were closed with one hole rubber stoppers through which a short piece of glass tubing was inserted. A four inch piece of pure gum rubber tubing was attached to the outer end of the glass tubing. Without clamping the rubber tubing the flasks were placed in a constant temperature water bath set at 30.5 degrees centigrade. Several trial runs proved this temperature to be close to optimum for most active growth of the organisms for the periods of incubation to be used. The dormant organisms in the soil were allowed to become active by incubation for 48 hours with the flasks open. At the end of 48 hours of incubation, the flasks were closed with pressure clamps placed on

the rubber tubing. After 4 hours of further incubation, the free end of the rubber tubing was attached to a suitable mercury manometer. The clamps were then released and the pressure inside the flask displaced the mercury in the manometer. This displacement was recorded in centimeters. The gasses which built up the pressure were assumed to be the end product of the metabolism of microorganisms present in the soil samples. This assumption was proved by running samples of soil in which microorganisms had been killed by either oven sterilizing or by treating with toluene. The control samples did not show any mercury displacement.

After the reading was recorded, the flask was disconnected from the manometer with pressure clamp open to permit the release of accumulated gas pressure and entrance of fresh air. The flasks were then closed and incubation continued with pressure readings repeated at the end of two additional consecutive four hour periods. By this procedure readings were made after 52, 56 and 60 hours of incubation. Trial runs showed these periods of incubation to give an adequate indication of the relative microorganic activity. Pressure built up during 8 or 12 hours of closed incubation was sufficient to break the flasks. Periods of incubation of less than 4 hours did not permit the accumulation of sufficient gas to establish relative activity.

Analysis of the data was made by running an analysis of variance on the readings recorded from one run of the constant temperature bath. This was done because of the variations in pressure observed for the check samples between consecutive runs of the water bath. These variations were established as being due to slight fluctuations in temperature brought about by minor fluctuations in electrical current of the local power generators.

## EXPERIMENTAL RESULTS

All soil samples treated with comparable field rates of the eight chemicals included in this study showed increases in gas pressure readings from 52 to 60 hours. The increase in pressure varied between rates of each chemical. Trichloroacetic acid, PCP, IPC and E.H. No. 2 gave a marked decrease in gas pressure in comparison to checks. The decrease in pressure in TCA and PCP treated soil samples was more severe than in IPC and E.H. No. 2. Analysis of variance determinations showed TCA at 10, 50, 100 or 150 lbs. per acre, PCP at four, eight or 16 pounds per acre, IPC at eight, 16 or 32 pounds per acre and E.H. No. 2 at two, four or eight pounds per acre had significantly reduced the microorganic activity in the soil samples at the 1% level. PCP at 2 pounds per acre and IPC at four pounds per acre did not decrease gas pressure significantly. TCA at rates of 100 or 150 pounds per acre reduced the microorganic activity in comparison to check samples more than did any of the other chemicals. The centimeters of mercury displacement for 100 lbs. per acre of TCA was 4.2, in comparison to an average of 11.4 for the check samples in this trial. The investigation indicated that applications of PCP in excess of 2 lbs. per acre have a depressing effect on microorganic activity. This depressing effect is reasonable con-

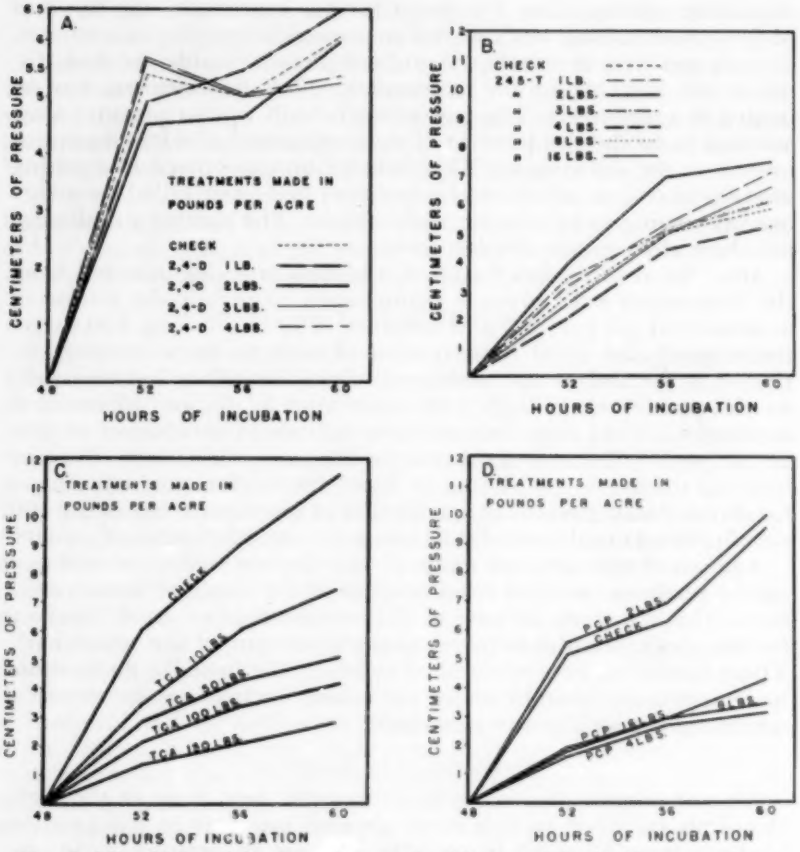


FIG. 1. Microbial activity in soil treated with several herbicides at various rates and measured in centimeters of mercury pressure after uniform periods of incubation. A. One, two, three, or four pounds per acre 2,4-D. B. One, two, three, four, eight, or 16 pounds per acre 2,4,5-T. C. Ten, 50, 100, or 150 pounds per acre TCA. D. Two, four, eight, or 16 pounds per acre PCP.

sidering the fact that PCP is being used generally as a wood preservative. TCA at accepted field rates for weed control however decreased the microbial activity more than did PCP at rates in excess of those recommended for weed control.

The graphs in Figs. 1 and 2 represent the gas pressure readings for each treatment rate of each chemical included in this study. Check lines are an average of pressure readings for all checks run at the time each chemical was studied.

Analysis of the recorded pressure readings for rates of 2,4-D, 2,4,5-T, or Endothal, showed that there had been no significant reduction in microbial activity by these chemicals. The lack of depression of microbial activity by 2,4-D using this method, checks with

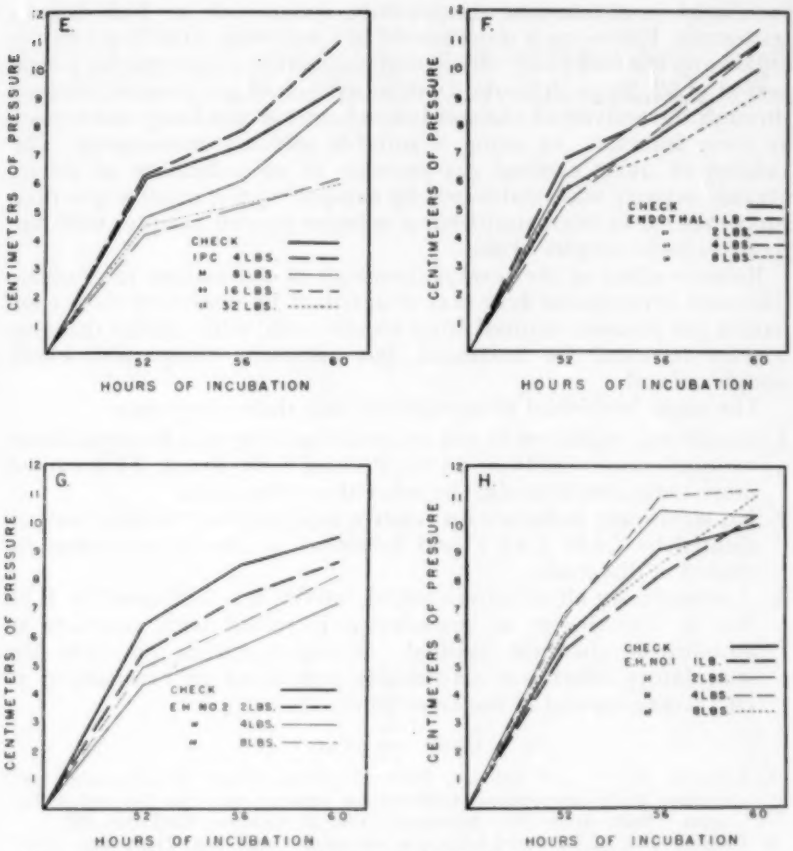


FIG. 2. Microbial activity of soil treated with several herbicides at various rates and measured in centimeters of mercury pressure after uniform periods of incubation. E. Four, eight, 16, or 32 pounds per acre IPC. F. One, two, four, or eight pounds per acre Endothal. G. Two, four, or eight pounds per acre E.H. No. 2. H. One, two, four, or eight pounds per acre E.H. No. 1.

the general consensus of opinion of other workers using plating methods.

The chemical, E.H. No. 1 showed pressure readings that were slightly higher than that of the check samples. The analysis of variance established a significant increase in microbial activity for the highest rate of E.H. No. 1, that of eight pounds per acre.

## SUMMARY AND CONCLUSIONS

One hundred gram samples of Barnes silt loam were treated at several field rates with eight herbicidal chemicals. Soil samples containing 35% moisture were placed in 250 cc. Erlenmeyer flasks and

incubated in a constant temperature water bath at 30.5 degrees centigrade. Following a short period of incubation to activate microorganisms, the flasks were closed and incubation continued for a total period of 52, 56 or 60 hours. Determinations of gas pressure evolved through the activity of the soil borne bacteria and fungi were made at these intervals, by using a suitable mercury manometer. The validity of using evolved gas pressure as an indication of microorganic activity was established by comparing the relative gas pressures evolved in oven sterilized or toluene treated samples with untreated check samples of soil.

Relative effect of the several chemicals at the various rates of application investigated here was established by analyzing data comparing gas pressure evolved from treated soils, with similar determinations recorded for untreated, but otherwise comparable check samples of soil.

The eight herbicidal chemicals fell into three categories.

1. Significant reduction in soil microbial activity was brought about by applications of TCA, PCP, IPC and E.H. No. 2. TCA caused more reduction than did the other three chemicals.
2. No significant influence on relative microorganic activity was indicated by 2,4-D, 2,4,5-T and Endothal at rates of treatment included in this study.
3. A stimulatory effect on microbial activity was indicated by E.H. No. 1. The degree of stimulation increased with increases in amount of chemical applied. At eight pounds per acre the stimulatory effect was statistically significant in comparison to check samples run at the same time.

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# Johnson Grass Control in Sugarcane

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IN LOUISIANA approximately 300,000 acres of sugarcane are grown each year for the manufacture of sugar. Another 125,000 acres are necessary for the rotation program, making approximately 425,000 acres devoted to the production of cane. Of these, 100,000 acres were estimated in 1950 (7) to be so badly infested with Johnson grass (Fig. 1) that a control program was necessary to obtain economic yields of cane. In addition to this acreage, headlands, ditchbanks, and roadsides of many additional plantations were infested with Johnson grass and constituted a potential threat to the cane fields.

The cane rotation practiced has contributed to the infestations. Sugar cane is planted in the summer and early fall of one year and is harvested in October, November, and December of the next year. This is the first or plant cane crop. The cane is then fertilized and cultivated, and another crop is harvested the next year in the fall. This is the first stubble crop. A great deal of this cane is then grown another year and harvested (the second stubble crop). As a result of

FIG. 1. Sugarcane field to be fallow plowed before planting to sugarcane showing Johnson grass infestation.

this system, Johnson grass plants being perennial, when once established in the cane row, grow and spread for a period of two or three years without being disturbed by plowing out the rows. There is also the same long period for the accumulation of new plants as seed germinate, and pieces of rhizomes are spread from one part of the row to another by cultivation and establish new plants.

As cane is harvested in October, November, and December, and planted in August, September, and October, it is obvious that a growing season must intervene between the last stubble crop harvested and the next planting of sugarcane. In the usual rotation this period has been used for the growing of a crop of soybeans to be turned under for organic matter and nitrogen, or a crop of corn and soybeans, the corn being harvested and the corn stalks and soybeans being turned under. This crop has perpetuated the Johnson grass from rhizomes and the plant cane crop starts off thoroughly infested with this weed. It has also been found that large quantities of seed are produced in many fields of infested cane and this residue of seed (6), contributes to the infestations.

Previous to 1940, a great deal of labor was available in the cane area and Johnson grass was held in check by continuous hoeing and digging. Mechanization was at a relatively low level. The impact of the war years, resulting in a shortage of labor and an almost complete mechanization of the field operations, built up over a period of years, greater and greater infestations, until the Johnson grass problem became a very serious one. As a result, in 1946, research was begun both by State agencies and members of the industry on an intensive scale to determine the best methods of reducing Johnson grass to a reasonable level, with the hope of eventual eradication. An analysis of the problems indicated information was essential on both the methods of control and the Johnson grass plant. The research was thus directed towards obtaining information on the following:

(1) The cleaning up of infestations of large Johnson grass plants in the year no cane is grown (i.e., the soybean year).
(2) The number of Johnson grass seed present in the soil, and the time they would remain viable.
(3) The prevention of reinfestations from seedlings in the plant cane crop so that the stubble crops could be raised economically.
(4) Methods of reducing Johnson grass infestations in the stubble crops to reduce seed production and also to obtain economic yields without necessarily eliminating Johnson grass.
(5) The eradication of Johnson grass plants on ditchbanks and headlands.

This paper summarizes the research done, the results obtained, and the program which has resulted from the investigations.

## THE ERADICATION OF LARGE JOHNSON GRASS IN INFESTED FIELDS

In 1941, Mr. Burden, manager of one of the large cane plantations, reported (3) that continuous plowing (8 to 10 plowings) during the year no cane was grown, gave very good reduction of the large John-

son grass plants in the field. This program was gradually adopted by many other individuals, and at present, on the large plantations, as much as 1,000 acres are fallow plowed, the term used to describe this operation, per year. Costs are estimated at present to be $12.50 to $15.00 an acre exclusive of the capital investment in the tractors and plows and without depreciation being taken into account.

Table 1 gives the results of a test by the Experiment Station with different numbers of plowings per season and the amount of live rhizomes per acre in a badly infested field. Indications are that more than 6 plowings are necessary for eradication.

*Table 1.* Effect of number of plowings on live rhizomes of Johnson grass in a sugarcane field in 1949.

| Operation† | No. plowings | Time between plowings in weeks | Live rhizomes in lbs. per acre | | | Per cent reduction |
|---|---|---|---|---|---|---|
| | | | 0–6″ soil | 6–24″ soil | Total | |
| Check | 0 | 0 | 16,912 | 2,796 | 19,708 | 0 |
| Plowing | 2 | 6 | 3,446 | 202 | 3,648 | 81.5 |
| Plowing | 3 | 4 | 5,527 | 309 | 5,836 | 70.0 |
| Plowing | 6 | 2 | 16‡ | 0 | 16 | 99.9 |

†Each experimental plot was 3/5 acre. Each figure represents average of three samplings of 1 square yard (total 27 square feet).
‡This represents 800–1000 feet rhizomes per acre.

A large number of chemicals have been tried experimentally to determine if Johnson grass could be eradicated in the cane fields more efficiently or at less expense than by fallow plowing. However, the large amounts of live rhizomes present in the fields (19,708 lbs. shown in Table 1), and the necessity of almost complete eradication, has made necessary the use of such high rates that costs become prohibitive and soil sterility with the resultant reduction in cane yields a dominant factor. Unless much more efficient chemicals are found, there seems little possibility of substituting chemicals for fallow plowing.

## Seed Production in Cane Fields

In certain areas fallowing gave satisfactory control of Johnson grass and little further attention was necessary, other than hand rogueing of the surviving plants from rhizomes and the few plants that came from seedlings. In other areas, reinfestation from seedlings was so bad (Fig. 2) that while a plant cane crop could be raised, first stubble yields dropped excessively, and second stubble yields became uneconomic and were not grown. This may be seen in Table 2 which are yields reported by Best and Gibbens (2), the managers of several plantations, all of which were badly infested with Johnson grass. While plant cane yields were increased, first stubble yields remained approximately the same after fallow plowing was practiced. In addition, a large number of seed were produced in the first stubble crop and the fields became reinfested with Johnson grass seed.

It became necessary to determine the number of seed present in infested cane fields, the effect of fallow plowing on these seed populations, and the length of time Johnson grass seed remained viable in

FIG. 2. Field planted to sugarcane after one season of continuous plowing, showing reinfestation from Johnson grass seedlings in fall.

the soil. A large number of soil samplings were made in plant cane after fallow plowing, in stubble fields, and in fields where corn and beans were raised and then plowed sufficiently to kill most of the rhizomes before planting to cane.

Results reported by Phillips and Chilton (6) indicated an average of 1,657,195 viable seed to the acre on 10 plantations where Johnson grass infestations in stubble cane were bad. The average number of seed present after fallow plowing for one season was 98,000, with

*Table 2.* Effect of fallow plowing on plant cane and succeeding 1st stubble crop yields on Cinclare plantation.†

| Crop | Yields in tons per acre‡ | | |
|---|---|---|---|
| | 1947–1948 No fallow plowing | 1948–1949 Fallow plowing | Difference |
| Plant cane | 16.06 | 22.77 | +6.71 |
| First stubble | 11.52 | 12.98 | +1.46 |

‡The yields are averages of ca. 1100 acres of plant cane and ca. 1100 acres of 1st stubble each year.
†From Best and Gibbens (2).

some fields showing as much as 250,000 per acre of soil 2½ inches deep. These seed occurred evenly in the row to a depth of 12½ to 15 inches giving 500,000 to 1,500,000 viable seed per acre capable of germination when conditions were favorable. Reinfestation after cleaning up a field by fallow plowing was very heavy, even where intensive hoeing was done. Seed populations were so heavy where corn and soybeans were raised that any seedling control was impossible.

The length of time that Johnson grass seed remain viable in the soil determines to a great extent the intensity of Johnson grass control to be applied commercially on a plantation. Three experiments were made to obtain information on this. In one, periodic soil sampling was done in a highly infested field in the part of the row which was not disturbed by cultivation and to which seed were not added. Results in Table 3 indicate that fallow plowing, a plant cane crop, and a first stubble crop (3 years) without the addition of new seed should reduce Johnson grass seed populations to a reasonable level. In two other tests, fields of approximately 2 acres each were fallow plowed, planted to cane and hand rogued as necessary in the plant cane and first stubble crops to prevent the addition of new seed. These fields were then planted to soybeans and only an occasional seedling was found. Initial samplings when the cane was planted indicated that approximately 90,000 seed per acre 2½ inches deep were present.

*Table 3.* Viability of Johnson grass seed in sugarcane field from 1947 through 1949.

| Date soil collected | Age† | Number soil samples used‡ | Number viable seed per acre 2½" deep | Per cent of original |
|---|---|---|---|---|
| March 19, 1948 | 8 mos. | 12 | 4,124,617 | 100.0 |
| April 3, 1949 | 20 mos. | 18 | 701,514 | 17.0 |
| November 9, 1949 | 27 mos. | 18 | 56,119 | 1.3 |

†July 20, 1947 considered last day seed matured as field plowed on that day.
‡Each sample 3.3 lbs.

These data indicate that a control program based on fallow plowing followed by intensive seedling control in the plant cane crop should reduce seed infestations to a satisfactory level.

## SEEDLING CONTROL

Cane is usually planted in fallow plowed lands in August and September. This gives sufficient time before cold weather for a crop of Johnson grass seedlings to grow and produce rhizomes (Fig. 2). In the spring, there is a period of three to three and a half months during which another crop of seedlings appears when conditions are favorable. This necessitates in the plant cane crop, control of seedlings six weeks to two months in the fall plus three to three and a half months in spring, or almost five months in all. Since the cultivation of the plant cane builds up the row about four inches with soil from the sides and middles, there is usually little difficulty with seedlings in the first stubble crop.

In the search for control methods, a large number of chemicals alone and together were tried experimentally. Chemicals in combination with flame cultivation were also tried (9). Previously, Simon, cooperating with Bourgeois and Barrow (1) had used 2,4-D as a preemergence spray and satisfactory control was obtained where seed infestations were not too high. After the screening program, two methods were found which did not cause injury to cane and which offered sufficient promise for large scale testing. These were (1) the use of 2,4-D as a preemergence spray at 2 lbs. acid equivalent per acre followed by flame cultivation (Fig. 3); the flame cultivation killed most of the surviving Johnson grass seedlings if done before a normal root system was developed by the seedlings following the effects of the 2,4-D, and (2) The use of TCA (sodium trichloroacetate) as a preemergence spray (Fig. 4) or post-emergence spray.

In the fall of 1948, large scale tests were begun in fallow plowed land, using tractor drawn three row sprayers, to obtain the necessary information on Johnson grass control, stands of sugarcane, yields of sugarcane and sugar, and costs. It had been found previously that only field scale experiments would be satisfactory as a measure of the materials and methods used, as invariably efficiencies dropped when small plot treatments were translated into field applications. It was

FIG. 3. Effect of 2,4-D preemergence sprays on Johnson grass seedlings. Untreated row left center.

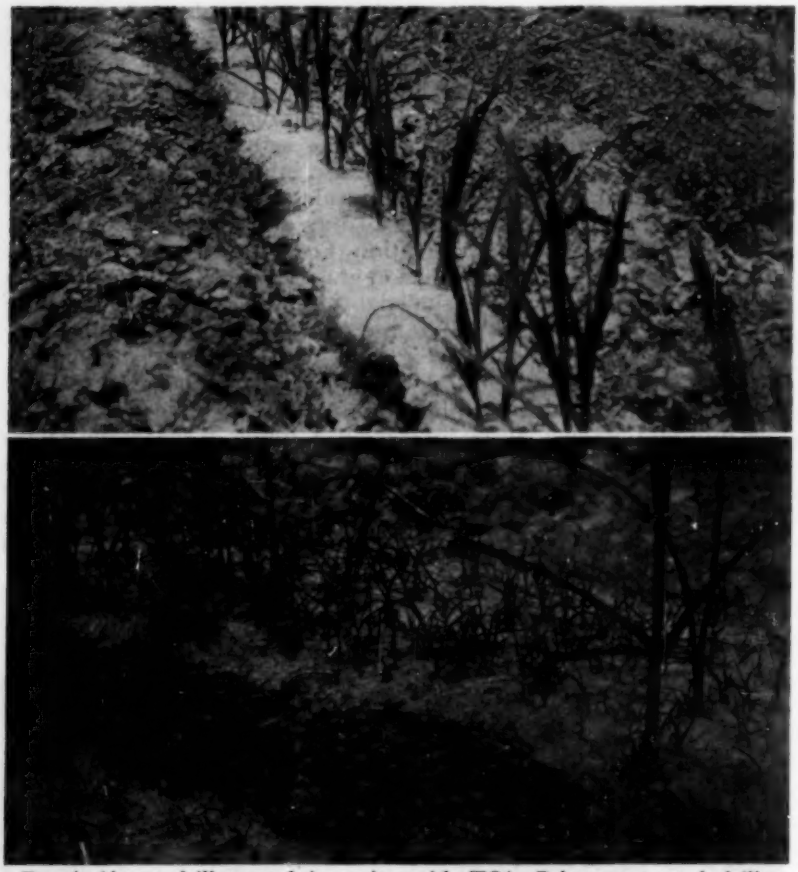

FIG. 4. Above: drill treated in spring with TCA. Below: untreated drill.

also found that efficiencies needed were so high that some hand rogueing was necessary and this practice was added to the program.

Table 4 gives the results of two years experiments on control of seedling reinfestations in the plant cane crop of sugarcane. The data show that 2,4-D used alone was insufficient for satisfactory control and that TCA was more efficient in general than 2,4-D plus flame cultivation. It is of interest to note that final control for the whole period of the plant cane crop should be 95 per cent or better to reduce Johnson grass infestations to a reasonable level. This requires almost complete control both in the fall and spring, a very difficult goal on a field scale.

The yields of plant cane and first stubble in the first series of tests and of plant cane in the second series of tests are given in Tables 5 and 6. Increments of both cane and sugar were sufficiently high to justify the program.

*Table 4.* Comparative control of Johnson grass seedlings in plant cane in 1949–1950.

| Treatment | Number tests | Check | | Treated | | Per cent control |
|---|---|---|---|---|---|---|
| | | Foot row counted | Stools per foot drill (1 each) | Foot row counted | Stools per foot drill (1 each) | |
| 2,4-D | 7 | 11,010 | 4.7′ | 23,150 | 20.0′ | 76.5 |
| 2,4-D + flame cultivation | 7 | 9,440 | 3.4′ | 51,160 | 52.3′ | 93.5 |
| TCA | 8 | 12,560 | 4.0′ | 20,600 | 79.6′ | 95.0 |

*Table 5.* Effect of Johnson grass and chemicals on yields of sugarcane in plant and first stubble crops.

| Treatment† | Number tests | Yields in tons cane per acre | | Increase (tons per acre) |
|---|---|---|---|---|
| | | Check | Treated | |
| *Plant Cane (2 Year's Tests)* | | | | |
| 2,4-D | 4 | 19.45 | 25.08 | 5.63 |
| 2,4-D + flame cultivation | 6 | 19.23 | 27.79 | 8.56 |
| TCA | 6 | 19.23 | 25.30 | 6.07 |
| *First Stubble (1 Year's Tests)* | | | | |
| 2,4-D | 3 | 17.04 | 18.53 | 1.49 |
| 2,4-D + flame cultivation | 3 | 17.04 | 31.38 | 14.34 |
| TCA | 3 | 17.04 | 29.27 | 12.23 |

†Treatments all included one hand rogueing in fall and two in spring. Check plots hoed as done on plantation.

*Table 6.* Effect of Johnson grass and chemicals on yields of sugar in plant and first stubble crops of sugarcane.

| Treatment† | Number tests | Yields in lbs. 96° sugar acre | | Increase (lbs. 96° sugar) |
|---|---|---|---|---|
| | | Check | Treated | |
| *Plant Cane (2 Year's Tests)* | | | | |
| 2,4-D | 4 | 3157 | 4159 | 1002 |
| 2,4-D + flame cultivation | 6 | 3224 | 4623 | 1399 |
| TCA | 6 | 3224 | 4303 | 1079 |
| *First Stubble (1 Year's Tests)* | | | | |
| 2,4-D | 3 | 3162 | 3173 | 11 |
| 2,4-D + flame cultivation | 3 | 3162 | 5480 | 2318 |
| TCA | 3 | 3162 | 5052 | 1890 |

†Same plots as in Table 5.

Costs were kept and it was found that the complete program, including chemicals, application, and hand rogueing amounted to $12.00 to $15.00 an acre. From this should be deducted the $6.00 to $12.00 an acre for hoeing which had been used previously. This amounts to $3.00 to $6.00 an acre for Johnson grass control in plant cane exclusive of fallow plowing. Best and Gibbens (2) give data of application on a field scale indicating increases in yields of cane and decrease in labor costs sufficient to justify the use of the chemicals.

## Stubble Cane

A large number of chemicals have been tried at different rates for the reduction of Johnson grass in badly infested stubble cane.

Godchaux (4) reported that sodium chlorate applied on the drill early enough gave economic increases in cane yields. However, certain varieties were most susceptible to sodium chlorate, and too late an application was often too severe in its effect on cane. Hagood (5) also presented results indicating that high rates of TCA or of sodium chlorate were valuable in reducing Johnson grass but were rather severe in their effect on cane.

The use of relatively low rates of TCA early in the spring on the drill before Johnson grass rhizomes sprout has shown promise (8). The data from several three row tests in 1950 given in Table 7 indicate economic returns in cane (Fig. 5). Further studies are needed on this type of control.

### Ditchbanks and Headlands

The elimination of Johnson grass on ditchbanks and headlands becomes necessary as infestations are reduced in cane fields, and also is needed on plantations where field infestations are low but ditchbank infestations are high. Godchaux (4) reported that sodium chlorate where used and amortized over a period of several years, costs less than the routine mowing and other practices necessary to keep

Fig. 5. Effect of TCA on suppression of Johnson grass rhizomes in sugar cane stubble. Hoed check on right.

*Table 7.* Effect of TCA on yields of sugarcane and sugar in stubble badly infested with Johnson grass in 1950.

| Test | Check (hoed) | Lbs. 100 per cent TCA per acre applied on 24" of drill | | |
|---|---|---|---|---|
| | | 3⅓ | 6⅔ | 10 |
| *Yields in Tons Cane to Acre* | | | | |
| St. Delphine | 4.38 | 10.20 | 12.55 | 16.38 |
| Evergreen 1 | 16.90 | 22.25 | 26.90 | 22.73 |
| Evergreen 2 | 15.88 | 19.98 | 17.93 | 22.63 |
| McCall | 15.66 | 20.02 | 22.84 | 24.56 |
| Averages | 13.21 | 18.11 | 20.06 | 21.58 |
| Differences | —— | + 4.91 | + 6.85 | + 8.37 |
| *Yields in Pounds 96° Sugar to Acre* | | | | |
| St. Delphine | 846 | 1670 | 2360 | 3061 |
| Evergreen 1 | 3318 | 4202 | 4796 | 4052 |
| Evergreen 2 | 2970 | 3806 | 3494 | 4056 |
| McCall | 2096 | 2703 | 3095 | 3759 |
| Averages | 2308 | 3905 | 3436 | 3732 |
| Differences | —— | + 787 | +1128 | +1424 |

Johnson grass under control. The results of the Experiment Station (5) indicated that TCA at 160 to 200 lbs. per acre killed large Johnson grass plants, but after it dissipated from the soil, seedlings came up and reinfestation occurred. Sodium chlorate at 600 lbs. per acre gave good control and soil sterility lasted long enough to prevent reinfestation from seedlings.

## DISCUSSION

The control of Johnson grass in sugarcane is still far from a permanent and easy solution. The necessity of such a high degree of control of seedling infestations over a long period of time requires an attention to detail difficult to obtain on a large plantation with overseers unaquainted with spraying equipment. Heavy rains often make it difficult to apply sprays and to use the flame cultivator at the correct time. However, where control practices have been used as recommended, the drop in Johnson grass infestations are very obvious.

The program at present indicates that a fallow plow program to start the plant cane crop free of rhizomes, plus intensive seedling control in the plant cane crop, and the reduction to the minimum of seed production in first stubble, either by chemicals or hand labor, should make it possible, after another fallow plowing, to bring Johnson grass under control. At the same time yields of cane should be increased more than enough to make a profit on the program. While not discussed in this paper, if Johnson grass is controlled, other weeds are taken care of as a result of the practices recommended.

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# Influence of Different Carriers upon the Inhibitory Properties of Growth-Regulatory Sprays[1]

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Several workers have reported that the activity of certain plant-growth regulators is influenced by the particular carrier employed in applying the materials to the plants (1,2,3,4). The compound 2,4-D is more inhibitory to Kidney bean plants when applied in a Carbowax 1500 aqueous solution than in wholly aqueous solution (1). The inhibitory effectiveness of oil sprays of 2,4-D is reduced little by rainfall whereas wholly aqueous sprays may be rendered almost noneffective by rainfall a few minutes after treatment (5). Rice (4) has reported a greater amount of absorption of $NH_4$ 2,4-D by leaves when Carbowax 1500 is included in aqueous solutions than occurs when wholly aqueous solutions are employed. The results presented herein are from additional studies on the effects of different carriers and formulations on the inhibitory properties of selected plant growth-regulators.

## Greenhouse Studies

Several greenhouse experiments have shown that oil sprays of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) are more inhibitory to young soybean and Kidney bean plants than aqueous sprays of the compounds. Volume of spray in these experiments did not exceed 5 ml. per sq. yd. Since certain commercial formulations of 2,4-D and 2,4,5-T may be used in either water or oil solutions certain greenhouse experiments were made to test the inhibitory properties of the compounds when applied in water and in oil. Esteron 44 (44 per cent isopropyl 2,4-D) and a 43 per cent isopropyl 2,4,5-trichlorophenoxyacetate formulation, both supplied by Dow Chemical Company, were diluted to appropriate concentrations with water and #2 diesel fuel oil and sprayed on young potted Kidney bean plants. The oil spray of both compounds was more inhibitory than the water spray, however the difference between the oil and water formulation of isopropyl 2,4,5-T was more striking than for isopropyl 2,4-D (Table 1).

In view of the increased effectiveness of the oil over the water spray another greenhouse experiment was made to test the influence of adding only 5 per cent oil to the carrier. Appropriate concentrations were made from the commercial preparations of the isopropyl esters of 2,4-D and 2,4,5-T by diluting with water, Deobase (a relatively innocuous light oil), and an oil-emulsion prepared by emulsifying Deobase in water containing 0.23 per cent Santomerse D.

Nine-day-old Kidney bean plants, selected for uniformity, were sprayed with 100 and 200 p.p.m. of the compounds in three different carriers at a volume rate of 5 ml. per sq. yd. Five plants made up

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*Table 1.* Mean green weight (g.) per plant of all trifoliolate leaf blades 18 days following spray application to young Kidney bean plants of isopropyl 2,4-D and isopropyl 2,4,5-T in water and #2 diesel fuel oil. Volume of spray was 5 ml. per sq. yd.

| Compound | p.p.m. | Carrier | |
|---|---|---|---|
| | | Water | Oil |
| Isopropyl 2,4-D† | 100 | 9.4 | 8.3 |
| | 200 | 9.3 | 5.8 |
| Isopropyl 2,4,5-T† | 100 | 9.7 | 3.7 |
| | 200 | 7.3 | 0.3 |
| Control | 0 | 8.7 | |

†Commercial formulations prepared by Dow Chemical Co., Esteron 44 (44 per cent isopropyl ester of 2,4-D) and 43 per cent isopropyl ester of 2,4,5-T.

each treatment. Green weights of all trifoliolate leaf blades above the simple leaves were taken as criteria of effectiveness. Yield data are given in Table 2.

The inhibitory effectiveness of both compounds was greater when applied in 5 per cent oil-emulsion and Deobase carriers than in a water carrier. Yield differences attributable to the oil-emulsion and Deobase treatments were not significant at the 5 per cent level.

## FIELD STUDIES

To test further the influence of different carriers on the inhibitory properties of growth-regulator sprays certain field-plot experiments were made using field-grown crop species as test material.

Replicated plots of soybean, var. Lincoln, were sprayed in 1948 with 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) in five different carriers. The solutions were applied at a volume rate of 3 ml. per sq. yd. with a DeVilbiss type MBC spray gun (pressure feed) fitted with type MBC-231 Decorators' combination spray head and veiling cap. The pressure and fluid adjustments were regulated so that a fine droplet spray was produced. A movable spray chamber, having a light metal frame and covered with a wind-resistant cloth, was used around the plots during the

*Table 2.* Mean green weight (g.) per plant of all trifoliolate leaf blades on Kidney beans 8 days following spray applications of isopropyl 2,4-D and isopropyl 2,4,5-T in 3 different carriers. Volume of spray was 5 ml. per sq. yd.

| Compound | p.p.m. | Carrier | | |
|---|---|---|---|---|
| | | Water | 5 per cent oil-emulsion | Deobase |
| Isopropyl 2,4-D† | 100 | 2.98 | 1.34 | 1.06 |
| | 200 | 1.92 | 0.50 | 0.22 |
| Isopropyl 2,4,5-T† | 100 | 2.78 | 0.62 | 0.28 |
| | 200 | 1.18 | 0.16 | 0.10 |
| Untreated | 0 | 4.68 | | |

Minimum significant difference between means at the 5 per cent level of probability is 0.57 g.; at the 1 per cent level is 0.76 g.

†Commercial formulations of Dow Chemical Company, Esteron 44 (44 per cent isopropyl ester of 2,4-D) and 43 per cent isopropyl ester of 2,4,5-T.

FIG. 1. Spray chamber used in spraying field plots.

spray operation (Fig. 1). The chamber was five feet in height and could be telescoped to fit the various standard size plots used in the experiments. Normally one end of the chamber, leeward to the wind, was left open to facilitate spraying. Plots consisted of 3 rows 18 ft. long from which the center rod portion of each row in the plot was harvested for yield determinations.

The oil-solutions and oil-emulsions of 2,4-D and 2,4,5-T were prepared by dissolving the acids in tributylphosphate (1 g. to 2 ml.) and then diluting to the appropriate concentration with #2 diesel oil. The emulsions contained 5 per cent #2 diesel oil and 0.33 per cent Santomerse D; they were made reasonably stable by passing the materials through a laboratory emulsifier three times. The acids were converted to the triethanolamine salts in preparing the wholly aqueous solutions and the formulations containing surface-active substances.

The yield data from two experiments are summarized in Table 3. The compound 2,4-D applied in a wholly-aqueous and a 1 per cent-Tween-20-aqueous spray was less inhibitory than when applied in the carriers 1 per cent Tergitol 7, 5 per cent oil-emulsion and #2 diesel oil. In general the latter two carriers appeared to be the most effective ones for both compounds. In comparison with a wholly aqueous carrier the inhibitory effectiveness of the compound 2,4,5-T was markedly improved by the addition of 1 per cent Tween 20 or 1 per cent Tergitol 7 to water solutions of the compounds. At the highest level the compound 2,4,5-T was applied, the oil-emulsion and oil sprays of the compound were significantly more inhibitory to the yeld of soybeans than similar applications in the other carriers.

In another field experiment the compound 2,4-D in three different carriers was applied to sugar beets. The treatments were made to plots consisting of 3 rows 18 ft. long when the roots were about one inch in diameter. The applications were made in the same way as described for the soybean experiments.

The yield data in Table 4 show that the oil and oil-emulsion sprays of 2,4-D were more inhibitory to sugar beets than the 0.5 per cent Santomerse D aqueous treatments. There was no significant differ-

*Table 3.* Mean yield of threshed soybeans in grams per plot (9 sq. yds.) following spray application of two plant growth-regulators in five different carriers. Applications in quadruplicate at 2 agent rates to plants in the late-blossom to early pod stage. Volume of spray was 3 ml. per sq. yd.

| Carrier | Yield | | | |
|---|---|---|---|---|
| | 2,4-D | | 2,4,5-T | |
| | 0.5 per cent | 1.2 per cent | 0.15 per cent | 0.30 per cent |
| Water† | 1551 | 1406 | 1326 | 1002 |
| 1 per cent Tween 20 (aqueous)† | 1560 | 1292 | 885 | 672 |
| 1 per cent Tergitol 7 (aqueous)† | 1526 | 1264 | 870 | 642 |
| 5 per cent oil emulsion | 1471 | 1170 | 872 | 378 |
| No. 2 diesel oil | 1448 | 1143 | 741 | 394 |
| Untreated | 1726 | 1696 | 1618 | 1612 |
| M.S.D. 5 per cent‡ | 100 | 100 | 87 | 87 |
| M.S.D. 1 per cent‡ | 135 | 135 | 117 | 117 |

†Triethanolamine salts used in these carriers.
‡Untreated plots excluded from analysis.

ence between the oil and oil-emulsion treatments. These results are in accord with the preceding data obtained from similar experiments on other test plants.

## DISCUSSION

The results of both greenhouse and field experiments show that the particular carrier employed in applying 2,4-D and 2,4,5-T is important in determining the inhibitory activity. The addition of certain surface-active agents, such as Tergitol 7, to aqueous solutions of the compounds increases the inhibitory properties over that of wholly aqueous sprays. In general oil-emulsion and wholly oil sprays of the compounds appear to posses higher herbicidal activity than wholly aqueous sprays or aqueous sprays containing some surface-active agents.

Judging from retention studies, not reported here, the varying effectiveness of the compounds in different carriers may be assignable in part to unlike retention by the foliage of the sprays. Additionally, the different carriers probably influenced the absorption and the translocation of the compounds in the same manner as described by Mitchell and Linder (3) for radioactive 2,4-DI. They found that cer-

*Table 4.* Mean yield of sugar beet roots in pounds per plot (9 sq. yds.) 106 days after spray treatment with 2,4-D in 3 different carriers. Applications in quadruplicate on 30 June 1948 at a volume rate of 5 ml. per sq. yd.

| Carrier | Yield | |
|---|---|---|
| | 0.2 per cent | 0.5 per cent |
| 0.5 per cent Santomerse D (aqueous)† | 32.2 | 13.5 |
| 5 per cent oil emulsion | 17.2 | 5.5 |
| No. 2 diesel oil | 21.6 | 7.2 |
| Untreated | 45.2 | |

Minimum significant difference between means at the five per cent level of probability is 5.0 lb.; at the one per cent level is 6.8 lb.
†Triethanolamine salt used.

tain surface-active substances increased the absorption and translocation of that compound in Black Valentine bean seedlings.

Although some use is being made now of surface-active agents in nonselective aqueous herbicidal sprays the search for and the screening of new surface-active substances should be made with a view to increasing further the herbicidal efficiency of sprays containing substances such as 2,4-D and 2,4,5-T. Some attention probably should be given to the use of oil-emulsions and oils as carriers for these herbicides particularly in regions where rainfall frequently makes aqueous sprays innocuous.

## SUMMARY

1. Oil and oil-emulsion sprays of 2,4-D and 2,4,5-T were more inhibitory to soybean, Kidney bean and sugar beet than wholly aqueous sprays.

2. The inclusion of certain surface-active substances in aqueous sprays of 2,4-D and 2,4,5-T improved their herbicidal properties.

3. The inhibitory effectiveness of aqueous sprays of commercial products of 2,4-D and 2,4,5-T was increased by incorporating 5 per cent of emulsified oil into the formulations.

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# Some Factors Influencing the Herbicidal Efficacy of Isopropyl N Phenyl Carbamate[1]

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## Introduction

The announcement of the effectiveness of Isopropyl N phenyl carbamate as a graminicide received considerable interest by weed research workers. However, early attempts to control grasses with this chemical resulted in rather disappointing control. Subsequent work has shown that this can be largely attributed to improper usage of the material. Since this material is supposedly a growth regulating substance, it was reasoned that it should behave in a manner similar to 2,4-D. Study carried on in Oregon proved that this was not the case and that specific conditions are essential to maximum effectiveness of this chemical.

## Review Of The Literature

The discovery of Isopropyl N phenyl carbamate as an herbicide was announced by Templeman (22). Thompson (24) reviewed the work on urethanes and pointed out the analogy of plant reactions to these substances and colchicine. Ennis (9) reported on the effect of IPC on Irish potatoes which was not significantly different from untreated controls. Allard (1) pointed out this similarity of plant responses to IPC and the hormone type materials. Taylor (21) indicated the variation of plant responses with respect to age and size of the plant in dealing with IPC in nutrient solutions.

Carlson (2) first pointed out the effectiveness of this compound in destructions of rhizomes of perennial grasses. However, Wolcott (26) reported that in field experiments no control of quackgrass was achieved until rates of eight to ten pounds per acre were applied and thoroughly incorporated in the soil. Even under these conditions, stand reductions of only twenty-five per cent were obtained. However, Freed and Bierman (15) were able to bring about significant control of quackgrass by proper use of this chemical. Dersheid (7) reports no outstanding success for the control of quackgrass and does not recommend its use. These indifferent results on the control of quackgrass perhaps can be explained on the basis of formulation and method of application as pointed out by Freed and Bierman (16).

The size and age of the plant as determining responses to IPC were pointed out by Ennis (10). However, in his experiment, it is readily apparent that formulation is important in plant responses. While the age of the plant is extremely important in determining responses, the placement of the application appears to be nearly as

[1]Published as Technical Paper No. 696 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Departments of Agricultural Chemistry and Farm Crops.

important. Ennis demonstrated that soil application gave markedly better results than application to the tops.

There is great differential response between plant species to IPC, as demonstrated by Taylor (20). This differential species response has given rise to agronomic use of the chemical demonstrated by Lachman (18), Freed and Bierman (15, 16), and Carlson (3).

The differential responses noted between the species may be observed as early as in the germinating stage. Therefore, a reasonable fact that this substance is a mitotic poison is brought out by Lefever (17), Deysson (8), and Ennis (11). It could be expected that this material would be most effectively used as a residual pre-emergence herbicide. This, of course, is borne out by the findings of Ennis and others in the differential responses of plants by age groups. It would follow, therefore, that since this material would be most effectively employed against annual plants during the germinating and early seedling stages that the length of residual effect would be of considerable importance, in light of delayed or prolonged germination. Since this substance is an organic chemical, it is to be presumed that various factors of environment could greatly modify the length of residual action. It is patent, however, that there would be a direct correlation between the rate of application and length of activity. De Rose (4) found that under conditions of his experiment, using fifty pounds per acre IPC, the chemical would persist in the soil for more than sixty days. Newman (19) found this substance to be toxic to the microorganisms of the soil. De Rose (5) demonstrated that the soil organisms were responsible in a large measure to reduction of activity of IPC. This, of course, was facilitated by conditions of high temperature and moisture.

While IPC is an outstanding member of the family of carbamates, it should be recognized that other chemicals related to this compound also possess activity. Templeman et al (23) prepared a number of compounds of this series and measured their activity. Freed (13) carried out a similar experiment with homologous series of alkyl alcohols. The Isopropyl derivative was by far the outstanding member of this group. It has been recently announced by Ennis (12), Witman and Newton (25), De Rose (6), and Freed (14) that the Metachloro derivative of IPC possesses high activity as an herbicide.

## MATERIALS AND METHODS

In studying the factors influencing the effectiveness of IPC, one must differentiate between whether the object is to control perennial grasses or annual grasses. While the factors bearing on residual toxicity are the same in both cases, the time, method, and rate of application vary considerably. The problem undertaken for this study is divided roughly on the basis of annual grass control and perennial grass control.

The materials used in this study included technical IPC, melting point eighty-four degrees Centigrade, 99.1 per cent pure, emulsifiable IPC formulated with ethyl acetate and ethylene dichloride, plus the

appropriate emulsifying agents, and containing either one or two pounds of technical IPC per gallon. The wettable IPC used, contained fifty per cent by weight technical IPC wetting agents and inert diluent. The one per cent dusts used were prepared from technical IPC and Pyrophyllite AB.

Field trials were usually carried out on square rod plots, employing a complete random block design with four replications. Timing of application rates and methods will be described in more detail with the presentation of experimental results.

Greenhouse trials were usually carried out in pots having a surface area of 0.2 square foot, and the applications were made to give a certain rate in pounds per acre of technical material based on this area. A counted number of seeds were planted to each plot and the percentage germination and the weight yield per plot was noted.

Trials conducted in the laboratory will be described in the text of the experimental results with presentation of experimental data.

## RESULTS AND DISCUSSION

### *Perennial Grass*

In attempting to control grass with IPC, it was decided that one of the important factors that might be contributed to the effectiveness of its use would be the stage of growth of the grass. It was important, therefore, to find the stage of growth at which the plant could be most effectively treated. This trial was set up by plowing a quackgrass sod and permitting the quackgrass to make regrowth. The material was then applied at emergence, three inch, six inch, and nine inch stages of development. The treatment consisted of application of ten pounds of IPC in one hundred gallons of aromatic weed oil per acre. Prior experiments had shown this to be the most feasible application. Table 1 is a summary of the data so obtained. Five quadrat counts per plot were taken to calculate the average per cent control in relation to a check or untreated area. The data clearly indicate the relationship between plant size and responses to the chemical treatment. It is inferred from these data that the oil serves as a vehicle for carrying the IPC into the plant and the greater the leaf area, as indicated by size and age of the plant, a correspondingly greater amount of the chemical will be carried into the plant and crown and upper rhizome.

In a series of four hundred plots established in 1947 to determine the effectiveness of IPC for the control of quackgrass, three principal factors were studied in a split plot factorial design. These factors were size and stage of development in relation to application of IPC,

*Table 1.* Comparison of age of quackgrass in response to IPC.

| Stage of growth when treated | Average per cent control |
|---|---|
| Emerging | 18.2 |
| 3 inch | 6.5 |
| 6 inch | 18.2 |
| 9 inch | 68.3 |
| Checks | 00.0 |

carrier or formulation of the material applied, and follow up practice, including tillage. The data from this trial were comparable to the data from Table 1, indicating that stage of development was a critical factor. Moreover, it was found that the carrier and follow up practice had a very significant effect on per cent control. In this trial, only the replications having a combination of oil carrier for the IPC, followed by cultivation gave any significant control of quackgrass. Table 2 summarizes this information. These data indicate little or no difference between the wettable and the emulsifiable form when applied with oil as the carrier. Since the solubility of IPC in aromatic oil is sufficient to dissolve the required amount of IPC used in this trial, it is not surprising to find so little difference.

*Table 2.* Summary of results obtained on quackgrass with IPC.

| Material | Rate per acre | | Tillage | Per cent of control |
|---|---|---|---|---|
| | IPC (lbs.) | Oil (gal.) | | |
| Check | – | – | None | 0.0 |
| Check | – | – | Disked | 18.3 |
| Wettable IPC | 5 | – | None | 2.8 |
| Wettable IPC | 5 | – | Disked | 31.6 |
| Emulsifiable IPC and oil | 5 | 120 | None | 47.9 |
| Emulsifiable IPC and oil | 5 | 120 | Disked | 84.9 |
| Wettable IPC and oil | 5 | 120 | None | 16.5 |
| Wettable IPC and oil | 5 | 120 | Disked | 81.1 |

It has been found in dealing with annual grasses that moisture and temperature relationships become critical in residual toxicity of IPC. Accordingly, a trial was established to determine the effect of times of application on the effectiveness of control by IPC. Table 3 presents this information. An attempt was made to have the quackgrass at the same stage of development at the different times of application. This was accomplished by mowing and permitting the regrowth to come back to the proper stage of development. It may be seen that the later summer applications are most effective. This is probably due to the shorter exposure to the high temperature of summer and the fact that soil moisture tends to be very low during the months of July and August under Western Oregon conditions. Similar trials carried out in the months of August, September, and October showed no significant difference at the five per cent level for the different times of application. Since IPC, even under the best of circumstances is not sufficiently effective to bring about complete control of quackgrass in one application, a series of mixtures of IPC with other chemicals was incorporated in a materials trial during the summer of 1950, This preliminary data is included in Table

*Table 3.* Time of application of IPC in relation to effectiveness.

| Time | Per cent control |
|---|---|
| May | 21.2 |
| June | 28.7 |
| July | 65.4 |
| August | 70.1 |

*Table 4.* Effectiveness of IPC in combination with maleic hydrazide.

| Treatment | Per cent control |
|---|---|
| Maleic Hydrazide (1 week early), 4 lbs. | 88.4 |
| IPC, 12 lbs. | |
| 3 Chloro IPC, 12 lbs. | 55.0 |
| IPC, 12 lbs. | 75.6 |

4. This information suggests that the mixture of Maleic Hydrazide and IPC is superior to IPC alone.

## ANNUAL GRASS CONTROL

Since IPC has been reported (8, 11, 17) to be a mitotic poison, it was reasoned that this material would be most effective against annual grass during the early germinating and seedling stage at which time cell division is occurring most rapidly. A greenhouse trial was established to evaluate the time of application with regard to the stage of development. Twenty seeds of Gray Winter Oats were planted in pots having an area of 0.2 square foot in Chehalis sandy loam soil. Immediately afterwards a one per cent dust of technical IPC was applied at a rate to give one pound of technical IPC per acre. A second treatment was made at the first leaf stage when the grain was three to four inches high and a third treatment made at the three leaf stage when the grain was seven to nine inches high. One month from the date of application the grain was harvested, together with the corresponding control grain, dried and weighed, and the reduction in yield was calculated in terms of a corresponding check. Table 5 presents the information gained from this trial.

*Table 5.* Effect of age of plant on response of Gray Winter Oat to IPC at 1 lb./acre.

| Stage of growth | Per cent reduction in per cent of check |
|---|---|
| Planting | 98 |
| First leaf | 14.2 |
| Third leaf | −1.2 |

This clearly demonstrates the rapidly decreasing effectiveness of application of IPC in growth stages. Observations made in the field however, under Western Oregon winter conditions, indicate that IPC in sufficiently heavy rates may be effective on susceptible species up to the early boot stage of development. On other intermediate or semi-resistant species of such plants as *Hordeum* and *Poa*, observations indicate the necessity of making applications at early germinating stages.

Since it becomes obvious that the length of residual effect of IPC is an important factor in regard to control of annual plants, it was felt necessary to determine the length of time that a given poundage of IPC would be effective. A Chehalis sandy loam soil, having a pH of 5.7 was put in pots having a surface area of 0.2 square foot. A one per cent dust of IPC was applied on the surface of this soil at a rate

to give the equivalent of 0, 2, 4, 8, and 16 pounds technical IPC per acre. These treatments were made in triplicate. Gray Winter Oats were then planted at the rate of ten seeds per pot and watered. The growth was harvested in fifteen days and immediately replanted. This process was continued until the heaviest rate of application gave a normal yield in relation to the check. The pots at all times were kept sufficiently watered to maintain normal growth. Table 6 presents this information expressed as the yield weight in per cent of check.

*Table 6.* Residual effect of IPC with variations in dosage.

| Pounds of IPC* | Days after treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 |
| 0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 2 | 0.0 | 4.9 | 33.8 | 88.4 | 110.2 | 111.0 | 106.0 |
| 4 | 0.0 | 0.0 | 0.12 | 50.5 | 104.5 | 106.5 | 98.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.80 | 93.8 | 95.0 | 98.0 |
| 16 | 0.0 | 0.0 | 0.0 | .016 | 17.3 | 66.0 | 100.9 |

*Rate in pounds per acre.

Because of the low solubility of IPC in water, it was not recognized at the time that the IPC might be chromatographed in the soil with a resulting concentration of the material in the botton of the pot. Since the soil was not inverted and remixed, this would tend to give a lower value for the length of activity and would be a weakness in this trial. The data derived from this work, however, clearly indicates a longer residual effect than found by previous investigations. The two pound rate remained active for nearly thirty days and the heavier rates of application correspondingly longer.

In an attempt to determine some of the factors involved in the length of residual effect of IPC, a trial was set up to determine the influence of temperature on the rate of breakdown and the influence of microorganisms on duration of activity. The procedure followed consisted of taking one thousand grams of Chehalis loam soil and sealing it in one gallon jars. One jar was autoclaved at fifteen pounds pressure for thirty minutes, one was held at 70° F, another held at 42° F. Each of the above three soil samples had been previously mixed with technical IPC, containing ten parts per million by weight in the final mixture. A fourth sample of soil (with no added IPC) was held at 70° F. Thereafter a fifty gram sample from each was drawn at weekly intervals and placed in a petri dish. Ten seed of Gray Winter Oats were planted in triplicate. The elongation of the emergent shoot of each seed was measured at the end of two weeks after planting. The soil moisture level was maintained at thirty per cent by weight throughout the experiment. Table 7 summarizes this information in terms of the per cent of the control.

It is patent from the foregoing data that the role of microorganisms in the destruction of IPC applied to the soil is extremely important. It can only be assumed from the longer residual effect in the autoclaved soil that the lack of microorganismal action would

*Table 7.* Longevity of IPC activity as determined by shoot elongation of Gray Winter Oat. Data expressed as per cent of check.

| Treatment | Sampling days after treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| | 14 | 21 | 28 | 35 | 42 | 49 | 56 |
| Autoclaved—10 ppm. IPC 70° F | —— | 4.1 | 9.1 | 4.1 | 8.3 | —— | 12.5 |
| Not autoclaved—10 ppm. IPC 70° F | 8.3 | 25.0 | 27.3 | 16.6 | 133.3 | 157.1 | 137.5 |
| Not autoclaved—10 ppm. IPC 42° F | 4.1 | 4.1 | 9.1 | 4.1 | —— | 3.6 | —— |
| Check—70° F | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

account for the greater activity. Further substantiation of this assumption would be borne out by the difference in length of residual activity at the 70° F temperature and the 42° F temperature. Obviously, the microorganisms would be more active at the elevated temperature, which would give rise to the more rapid breakdown of the IPC.

In light of these findings, a further trial was established in the greenhouse to evaluate the effect of autoclaving as compared to non-autoclaving and additional adjustments of soil pH by calcium carbonate or lime. This was set up in triplicate on a Chehalis loam soil, having a pH of 5.4. Lime was applied to both autoclaved and unautoclaved soil at rates of 0, 1000 pounds per acre, 2000 pounds per acre, 4000 pounds per acre, and 8000 pounds per acre. The IPC was applied as a one per cent dust at a rate to give four pounds of technical IPC per acre. The soil was planted and moistened down immediately, the crop harvested in ten days and immediately replanted at ten day intervals thereafter. Optimum moisture was maintained throughout the experiment by frequent overhead watering. Table 8 summarizes these data.

The information presented herein again points to the important role of microorganisms in the breakdown of IPC. The role of lime, while not exactly known, appears to play an important part in loss of activity of IPC. There could be two obvious explanations for the importance of lime in this loss of activity. The first being alkaline hydrolysis of IPC, and the second, stimulation of organisms or an organism bringing about hydrolysis or destruction of IPC. Qualitative differences of microorganisms in the soil could well account for the

*Table 8.* Effects of liming and autoclaving on longevity of IPC as determined by shoot elongation of Gray Winter Oat. Data expressed as per cent of check.

| Treatment | | | Planting and days following treatment | | | |
|---|---|---|---|---|---|---|
| Autoclave | IPC (lbs.) | $CaCO_3$ (lbs.) | First 10 | Second 20 | Third 30 | Fourth 40 |
| Yes | 0 | 0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Yes | 4 | 0 | 0.0 | 0.0 | 0.0 | 26.1 |
| Yes | 4 | 1000 | 0.0 | 0.0 | 0.4 | 84.6 |
| Yes | 4 | 2000 | 0.0 | 0.0 | 0.0 | 118.4 |
| Yes | 4 | 4000 | 0.0 | 0.0 | 21.2 | 96.5 |
| Yes | 4 | 8000 | 0.0 | 0.0 | 34.0 | 118.4 |
| No | 0 | 0 | 100.0 | 100.0 | 100.0 | 100.0 |
| No | 4 | 0 | 0.0 | 0.0 | 11.5 | 104.9 |
| No | 4 | 1000 | 0.0 | 87.9 | 91.4 | 98.3 |
| No | 4 | 2000 | 0.0 | 81.1 | 90.4 | 90.5 |
| No | 4 | 4000 | 0.0 | 60.2 | 111.7 | 98.6 |
| No | 4 | 8000 | 0.0 | 59.5 | 90.7 | 114.2 |

differences found in the residual activity of this chemical. Further support of the influence of lime on breakdown of IPC will be found in Table 9. Flats of Chehalis sandy loam soil were treated in duplicate at the rate of 0, 4, 8, and 16 tons of lime per acre. They were immediately treated with a uniform application of IPC at a rate to give four pounds per acre. Thirty-six seed of Gray Winter Oats were planted per flat. Observations were made in two weeks and the flats immediately replanted. Observations and data again were taken at the end of two weeks.

*Table 9.* The residual effect of 4 pounds of IPC on Gray Winter Oat as influenced by liming.

| Liming | Row | First planting | | | Second planting | | |
|---|---|---|---|---|---|---|---|
| | | Plants emerged | Length (inches) | Green wt. (grams) | Plants emerged | Length (inches) | Green wt. (grams) |
| None | 1 | 0 | — | — | 0 | — | — |
| | 2 | 0 | — | — | 0 | — | — |
| | 3 | 0 | — | — | 0 | — | — |
| 4 tons | 1 | 0 | — | — | 11 | 4⅛ | 1.60 |
| | 2 | 0 | — | — | 11 | 4⅛ | 1.50 |
| | 3 | 0 | — | — | 11 | 5 | 1.51 |
| 8 tons | 1 | 0 | — | — | 12 | 5 | 2.00 |
| | 2 | 0 | — | — | 11 | 5 | 2.05 |
| | 3 | 0 | — | — | 11 | 5 | 2.16 |
| 16 tons | 1 | 0 | — | — | 12 | 4⅛ | 2.10 |
| | 2 | 0 | — | — | 12 | 4⅛ | 2.30 |
| | 3 | 0 | — | — | 12 | 5 | 2.35 |

From the foregoing data, it is obvious that the lime definitely reduced the residual effect of the IPC, the breakdown coming between the 0 and 4 ton rate of application, however, added amounts appeared to significantly increase the growth. It should be noted that field observations have indicated considerable variation in the residual activity of IPC on different soil types. Thus, on a heavy clay soil, poorly drained, the residual activity has been observed to be up to one third longer than on a porous, well drained soil.

Since it has been demonstrated that the preliminary action of IPC comes through the soil, it would appear that moisture would be something of a critical factor in the effectiveness of this chemical, particularly in reference to bringing it into intimate contact with the germinating seed, or roots of seedling plants. It has been found in the field that under somewhat arid conditions better results may be achieved in the way of grass control by first tilling the IPC into the soil. A preliminary trial was established in pots in the greenhouse where surface of the soil was kept dry before applying IPC, where the surface would be moistened, and where water was added to moistened soil. The plants were harvested in two weeks and the control calculated in per cent of check. Table 10 summarizes the data thus obtained.

It is quite apparent from these data that water plays an important role in the effective use of IPC. This role appears to be that of bringing the IPC into intimate contact with the germinating seed or

*Table 10.* The influence of water on the effectiveness of IPC.

| Soil surface | Per cent control |
|---|---|
| Dry | 18.2 |
| Moist | 87.6 |
| Moist + $H_2O$ | 98.7 |
| Check | 00.0 |

young seedling plant. Field observations under arid conditions further substantiate this evidence. Under these conditions, when attempting the control of annual grasses, it is necessary to till the chemical into the soil to assure the proper intimacy of contact.

While water is important in assuring effectiveness of an IPC treatment, it also plays an important part in detoxification of the chemical. This arises in two ways: (1) by leaching the chemical from the soil, and (2) by providing the proper environment for microorganismal action. Table 11 presents data showing the effect of water on the residual toxicity of IPC when mixed with soil at the rate of 10 ppm and held at 0, 15, and 30 per cent moisture at 135° F. Samples of the soil were taken at seven day intervals and assayed for IPC with Gray Winter Oats. The results are expressed as shoot length in per cent of check.

*Table 11.* Longevity of IPC residual activity as affected by different moisture levels. Growth of Gray Winter Oat calculated as per cent of check.

| Treatment | Days after treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 |
| 10 ppm IPC 15 per cent $H_2O$ | — | 5.5 | 6.6 | 28.6 | 58.3 | 57.1 | 100.0 | 87.5 |
| 10 ppm IPC 30 per cent $H_2O$ | — | 7.3 | 25.0 | 85.7 | 100.0 | 100.0 | 87.5 | 87.5 |
| 10 ppm IPC 00 per cent $H_2O$ | — | — | — | 5.1 | — | — | — | — |
| Check 30 per cent $H_2O$ | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Since moisture is so patently important to the effectiveness of control, it was only natural to wonder how deep IPC might be leached into the soil. Leaching tubes were prepared from forty-five millimeter glass tubing lined with vinylite plastic tubing. Chehalis soil was firmly packed into the tube. After the leaching procedure the plastic tube was removed and the soil divided into one inch sections. This soil was placed in petri dishes and moistened and ten oat seeds were planted therein. After ten days, the shoot was measured and the per cent inhibition calculated in terms of the check. Table 12 is a summary of this data. Treatments were as follows:

1. Chehalis fine sandy loam with moisture level near field capacity was placed and tamped to firmness in the lined column. A filter was placed on the soil surface, then one gram of technical IPC was placed on the filter. Two inches of water were filtered through the IPC and down into the soil column. Twenty-four hours after the treatment, the column was removed and plantings made.

2. Oven dry soil was screened through a twenty mesh screen, placed in the lined column, and tamped to firmness. A water

solution of IPC at a concentration of 200 ppm was added to the soil column through a dropping funnel. The delivery was adjusted to equal the speed of penetration. Moisture equivalent to four inches of the 200 ppm IPC in water carrier was used as the treatment. Twenty-four hours after the moisture had reached the bottom of the soil column, the soil column was removed and samples taken for indexing IPC activity.

3. Treatment number three was the same as two except that technical IPC and water were shaken together at room temperature to form a saturated solution. The equivalent of four inches of moisture of this concentration was applied in the same manner as number two.

4, 5, & 6. Oven dry, screened soil was placed and tamped to firmness in the leaching apparatus. Water was added to bring the soil to a well moistened condition upon equilibrium. Then the saturated IPC solution was added at the rate of one inch in treatment number four, one half inch in treatment number five, and one fourth inch in treatment number six. Twenty-four hours later the treated soil columns were removed from the cylinders, samples taken, and plantings made to determine activity.

7. The soil column was moistened and one tenth gram of technical IPC was placed on the surface. Twenty-four hours later samples were taken in the prescribed method. Data consisted of counting the number of shoots emerging per sample and the shoot or plant length at fourteen days after planting.

This information would indicate that IPC is not readily chromatographed in the soil, and with ample moisture and allowed adequate drainage, would distribute itself throughout the soil profile.

In evaluation of the biotoxicity of various compounds, the matter of specificity is often encountered. It would be expected that a similar situation might be encountered in dealing with IPC. Trials have been run from a number of species of grass and dicotyledonous

*Table 12.* Depth of leaching of IPC in soil columns.

| Treatment | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type carrier | 4" water on tech IPC | | 4" 200 ppm IPC solution | | 4" of sat. IPC solution | | 1" of sat. IPC solution | | ½" of sat. IPC solution | | ¼" of sat. IPC solution | | Tech IPC on surface | |
| Pretreatment soil moisture | Field capacity | | Oven dry | | Oven dry | | To 21% | | To 21% | | To 21% | | To 21% | |
| Depth of crossection from surface inches | Plants emerged | Per cent inhibited | Plants emerged | Per cent inhibited | Plants emerged | Per cent inhibited | Plants emerged | Per cent inhibited | Plants emerged | Per cent inhibited | Plants emerged | Per cent inhibited | Plants emerged | Per cent inhibited |
| 1 | 0 | 100.0 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 1 | 99 |
| 2 | 3 | 91.7 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 1 | 98 |
| 3 | 4 | 91.7 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 2 | 90 | 2 | 97 |
| 4 | 5 | 91.7 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 3 | 20 | 6 | 95 |
| 5 | 4 | 91.7 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 5 | 15 | 7 | 90 |
| 6 | 3 | 87.5 | 0 | 100 | 2 | 95 | 0 | 100 | 0 | 100 | 8 | 20 | 8 | 75 |
| 7 | 3 | 75.0 | 0 | 100 | 6 | 60 | 0 | 100 | 0 | 100 | 7 | 20 | 8 | 40 |
| 8 | 6 | 58.4 | 0 | 100 | 7 | 40 | 0 | 100 | 7 | 75 | 8 | 15 | 9 | 30 |
| 9 | 5 | 50.0 | 0 | 100 | 7 | 25 | 0 | 100 | 8 | 65 | 8 | 10 | 10 | 5 |
| 10 | 7 | 00.0 | 0 | 100 | 6 | 0 | 0 | 100 | 8 | 10 | 8 | 0 | 10 | 0 |

plants to determine this specificity of action. Table 13 presents a summary of information gained from greenhouse trials with two carbamates, IPC and 3 Chloro IPC (Isopropyl N 3 chloro phenyl carbamate), on a number of grassy plants. It is interesting to note that for the most part the IPC appears to be most effective on the species of the *festucoideae* and the 3 Chloro appears more effective on the species of *panicoideae.*

*Table 13.* Species response to carbamates. Per cent control in terms of untreated check.

| Grass | IPC | 3 Chloro IPC |
|---|---|---|
| Bromus tectorum | 99.9 | 71.8 |
| Lolium multiflorum | 100.0 | 65.6 |
| Festuca myurus | 100.0 | 73.2 |
| Avena fatua | 91.6 | 93.1 |
| Poa annua | 83.4 | 88.7 |
| Digitaria sanguinalis | 42.2 | 97.5 |
| Echinochloa crus-galli | 21.6 | 86.0 |
| Setaria viridis | 35.9 | 90.6 |
| Panicum capillare | 58.6 | 98.2 |

In an attempt to evaluate those factors which might influence the agronomic use of carbamates, the attention of the writer was called to climographs. It was found that for the state of Oregon, the probable effectiveness of IPC and the optimum time of application could be predicted from a climograph for a given region. These climographs are constructed by plotting the average monthly precipitation against mean monthly temperature. For this area, the climograph could be further divided on the basis of mean annual rainfall which was of further aid in determining optimum time of application. For Oregon conditions of warm dry summers, the climograph has an inverted apex occurring in July or early August. For those many regions where failures have been reported with IPC, it would appear that there was either a resistant species present, or the temperature-moisture ratio was in improper relationship to the proper use of the chemical. Thus, for some regions of the United States, the climograph takes the appearance of a two dimensional cone, showing an apex in the summer months, or indicating high summer moisture which with summer temperatures would provide conditions that would favor rapid destruction of IPC.

## SUMMARY AND CONCLUSIONS

Isopropyl N phenyl carbamate (IPC) is gaining considerable acceptance as an herbicide in certain regions. It has proven valuable for the control of weedy annual grasses in legumes and certain other crops. Moreover, it has shown some promise for the control of certain perennial grasses.

Investigations with IPC have proven this chemical to be a valuable adjunct to the herbicide field. However, to attain maximum effectiveness with this chemical, it is necessary to have certain specific conditions for its use. Studies on factors that have influence on the effectiveness of this chemical have shown: 1. That it is subject to bio-

chemical specificity and is more actively effective on species of *festucoideae* than *panicoideae*. 2. The residual activity of this chemical is important in achieving the control of young seedling plants and the loss of this activity is in a large measure due to an attack by microorganisms. 3. Since IPC is a mitotic poison, it is most effectively used against germinating seeds and very young seedling stages. 4. Moisture is essential to bring the IPC into intimate contact with the plant to be controlled, but moisture with high temperature may result in more rapid destruction of the chemical. As a consequence, this chemical has proven more effective for the control of winter annuals by reason of its use during periods of cooler weather at a time when microorganismal activity is low. 5. The control of perennial grasses with IPC presents a different problem than the control of annual grasses. This problem necessitates: (a) Application of the IPC in oil, which serves as a vehicle to carry the IPC into the plant and (b) cultivation to assure intimate contact of the IPC with the rhizomes and stolons of the undesirable grass.

ACKNOWLEDGEMENTS

Due and grateful acknowledgement is given to the graduate and laboratory assistants who have helped in the course of these investigations. Particular recognition is taken of the help given by W. H. Kosesan and H. E. Bierman.

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# Fogging Ribes, White Pine, and Brush with 2,4-D by Helicopter[1]

By H. R. Offord, *Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture,* and C. M. Voss, *U. S. Helicopters, Inc.*

The herbicides 2,4-D and 2,4,5-T are used extensively in the Western States for killing *Ribes*[2] (3), the noxious plants that spread the destructive blister rust *(Cronartium ribicola* Fischer) to white pines *(Pinus* L.). Tests of the thermal fogging unit here described relate to the broadcast application of low dosages of 2,4-D as a wet oil-fog designed to defoliate and damage ribes plants without significantly damaging associated white pines. Tests were made at Stockton, and near Pescadero, Calif., in 1950.

A helicopter equipped with a conventional boom has already been used effectively for broadcast spraying of ribes and brush with 2,4-D and 2,4,5-T on a few selected white pine sites[3] (4). For extensive use, however, the combination of rugged terrain, reduced payload of the helicopter at elevations of 3,000 to 7,000 feet, and the need for about 10 gallons of diluent per acre restricts the maneuverability of the ship and adds to the cost per acre. Under the conditions noted any reduction in the per acre weight of toxicant and diluent would mean lower costs and greater safety. Concentrates of 2,4-D or 2,4,5-T in finely dispersed form can be used without hazard from drift in forest and range areas remote from sensitive crop plants.

2,4-D and 2,4,5-T are more toxic to ribes and many other broadleaved shrubs than to most conifers, but this differential in toxicity is not always large enough to prevent damage to trees when these herbicides are applied broadcast by aircraft. Young conifers may be severely damaged by the pound or more per acre of 2,4-D or 2,4,5-T needed to kill mature ribes bushes in a single application. Development of more selective toxicants, or better timing and control of the dosage applied, would therefore greatly increase the usefulness of broadcast chemical treatment in forest-protection work. Repeated applications of sublethal dosages of chemical that would defoliate ribes and suppress their axillary buds without harming pine would eventually kill the ribes or contribute significantly to their natural

[1]Tests were planned and conducted with the help of W. V. Benedict, W. S. Burrill, D. Dunkle, A. London, Wm. Matero, C. R. Quick, E. Schieder, and E. Schlesinger. For approval and assistance in making these tests on private property in San Mateo County, the authors are indebted to the Kelly-Mattei Ranch near Pescadero, Calif., to J. J. McNamara, farm advisor for San Mateo County, and to M. J. Leonard, the agricultural commissioner for San Mateo County. Facilities used by the Bureau of Entomology and Plant Quarantine at Berkeley, Calif., are maintained in cooperation with the University of California, College of Agriculture, through the School of Forestry.

[2]The generic name *Ribes* and the common name "ribes" are used to indicate currants and gooseberries.

[3]Also unpublished reports of joint tests conducted by the U. S. Forest Service and the Bureau of Entomology and Plant Quarantine.

suppression by competing trees and other less sensitive vegetation. Such treatment might be termed the "chemico-ecological" suppression of ribes rather than immediate chemical eradication.

Ribes is a low-growing shrub and often is heavily screened by taller brush and trees. Unless it grows in the open or the plant is young, the ribes is seldom killed by one spraying from aircraft. Yet foliage and stem can be damaged with relative ease. Previous field tests on *Ribes roezli* Regel, which is highly sensitive to 2,4-D, showed that all foliage and much of the stem could be killed by thorough coverage with aqueous 2,4-D at concentrations of 25 to 50 p.p.m., or by dosages of 6 ounces or less of 2,4-D acid per acre. Other species of *Ribes* may require more than 6 ounces per acre of 2,4-D or 2,4,5-T to defoliate them, but regardless of species reaction, there should always be large differences between the dosages needed to defoliate and those needed to kill.

It is difficult to achieve uniform distribution of a low dosage of toxicant, especially over rugged forested land. Effective saturation of space from the break up of a given volume of liquid is best achieved by small drops (2, 5). One gallon of liquid broken up into drops of 33-micron diameter would provide 32,000 drops per square inch over an entire acre (2). In the fogging of a toxicant from aircraft, large particles are obviously less subject than small ones to drift and to influence by weather and other noncontrollable factors. The problem, therefore, was to adjust the particle size so that the resultant mist would settle, penetrate the canopy of brush, and deposit a defoliating residue of 2,4-D on ribes without damaging associated white pine.

## PREVIOUS RELATED WORK

Fogging devices, mounted either in ground equipment or in aircraft, are useful to entomologists in obtaining effective saturation of space with small volumes of toxicant, and also in obtaining a deposit of insecticide where a low residue meets the needs of the control job. Basic information on the deposition of aerosol particles has already been published (2, 5, 6) and will not be reviewed here. In plant-suppression work, the consensus has been that requisite weights and volumes of herbicides are too large for economical application with fogging machines.

When the present tests were planned, no previous experience or published data were available on several problems involved in helicopter application of a thermal-generated fog of 2,4-D. The chief problems were the possible thermal decomposition of 2,4-D ester, the control of particle size as needed to ensure an appreciable residue, and the limitations of weather on drift and settling of the herbicidal fog in relation to air speed and height of the helicopter. In the absence of specific data on the thermal decomposition of 2,4-D at 500–800° C. (the temperatures to be expected in the exhaust stacks),[4]

[4]Virgil H. Freed, agronomist at Oregon State College, advised the senior author by letter of March 23, 1950, as follows: "I might relate our own experience with

care was taken to exclude water from equipment and materials. The butoxyethanol ester of 2,4-D, which has a low vapor pressure, was selected so as to minimize loss from volatilization of the anticipated low residue on ribes foliage.

## PRELIMINARY TESTS OF EQUIPMENT

A thermal-type aerosol fogging unit was installed on a Bell 47-B helicopter for preliminary tests at the Stockton, Calif., airport on March 22, 1950. This unit consists of a vaporizing head mounted on the inverted exhaust stack on each side of the ship. Oil and dissolved toxicant are pumped directly into the two thermal heads. Two needle valves set in the feed line control the rate of flow. In flight the pilot can control the supply of oil entering each head.

At any given rate of discharge into the thermal heads the resultant fog will be made up of particles of varying size, depending upon the temperature of the head, the speed of the ship, the physical properties of the oil-toxicant, and the air conditions. Nevertheless, a so-called dry fog can be changed to a wet one by regulating the rate of flow of the oil-toxicant to the thermal heads. To assure an appreciable deposit of herbicide, an attempt was made to produce a wet fog having many of its particles 50–100 microns in diameter. At a discharge rate of about 65 gallons per hour per head, a large fraction of the fog seemed to be heavy enough to settle from a height of 40 feet in about 2 minutes. The estimated average diameter of water droplets falling in air would be about 100 microns if they fell 40 feet from rest in 0.73 minutes and about 50 microns if they fell the same distance in 2.70 minutes (1).

At 65 gallons per hour for each head and at 25 p.s.i. pump pressure, the general characteristics of the fog at a ship speed of 15 and 25 m.p.h. and the wind at about 5 m.p.h. are shown in Fig. 1, *A* and *B*. The twin column of fog tended to stream backward more and more in a horizontal line as speed was increased above 20 m.p.h., but at 15 m.p.h. the fog was partially controlled by rotor wash from heights of 10 and 30 feet. Gusty winds of 5 m.p.h. or more, which prevailed at Stockton, prevented adequate control of the fog at a height of 40 feet and at 20 m.p.h. or more ship speed. On the basis of these preliminary tests, it appeared that virtually still air and a ship speed of about 15 m.p.h. would be needed for satisfactory control and deposit of the fog. It was found that by turning the thermal heads downward and in a slightly more inboard direction the column of fog was more solid and uniform. Compare *A* and *B* with *C* and *D* in Fig. 1.

## FOGGING TESTS

On the Kelly-Mattei ranch, near Pescadero, Calif., on May 8, 1950, the following series of fogging tests were completed:

the Bessler fog machine where...temperatures...are rather more in the order of 350–600° C., where we applied 2,4-D ester in oil. With this machine we found a slight reduction in potency of the material, but this slight reduction in no way affected the practical application of the 2,4-D ester."

Series 1. Tests with oil only, to observe general characteristics of the fog column, and to note drift and settling of the fog when delivered from heights of 100, 50, 25, and 10 feet above the ground at air speeds of 25 and 10 m.p.h. (Flights 1–8.)

Series 2. Tests of 2,4-D in oil on potted ribes and white pine plants. Ship flying at height of 20 feet above ground and at speeds of 25, 20, 15, and 10 m.p.h. (Low-level tests. Flights 9–12.)

Series 3. Tests of 2,4-D in oil on potted ribes and white pine plants. Ship flying at height of 100 feet and at speeds of 10, 15, and 20 m.p.h. (High-level tests. Flights 13–15.)

Series 4. Tests of 2,4-D in oil on coyote brush *(Baccharis pilularis* DC.) to determine the uniformity of foliage kill in practical type fogging treatment. All ribes and pine plants not used in the previous tests were set out on the area. (Low-level test. Flight 16.)

In series 1 a light-medium machine oil (gravity API 27.5, flash point 285° F., viscosity (Saybolt) at 100° F., 65 sec.), and an aromatic weed-killer oil (gravity API 13.3, flash point 230° F., viscosity (Saybolt) at 100° F., 38.8 sec.) were compared as fogging oils. On the basis of visual evidence both oils were satisfactory. The aromatic oil is cheaper than the machine oil, but the amounts used are so small that the price of the oil is not significant. Glass plates placed in the open, both horizontally and vertically, at intervals along a line at right angles to the line of flight were used to sample the 60-foot wide strip that was to be used later in the fogging tests on potted ribes and pines. Appreciable oily residues collected on plates in the following tests:

| *Flight* | *Height in feet* | *m.p.h.* |
|---|---|---|
| 1 | 10 | 10 |
| 3 | 25 | 10 |
| 4 | 25 | 25 |
| 5 | 50 | 10 |
| 6 | 50 | 25 |

For series 2 (flights 9–12 in Table 1) the butoxyethanol ester of 2,4-D, a proprietary product containing the equivalent of 4 pounds of acid per gallon, was mixed with light-medium machine oil in the proportion of 1 part of toxicant to 15 parts of oil. On each of these test flights potted *Pinus monticola* and *Ribes roezli* were placed in predetermined spots across the strip of brush and grassland to be fogged.

The plants of *Ribes roezli* were healthy, 2 or 3 years old, and of seedling origin grown in the greenhouse at Berkeley. Most of the *Pinus monticola* plants were acquired shortly before the tests; they had been in a nursery seedbed for several years, but many were only 4 to 6 inches tall. Removal of the pines from the nursery bed, after being undisturbed for some years, resulted in a very low root-shoot

ratio in these transplants, and it was expected that some of them would not survive the shock of transplanting.

All pines were placed in the open to expose them to the greatest risk of damage. Two ribes bushes and a pine were placed in the open and under brush estimated to provide light, medium, and heavy cover or screening. After the fog from each test flight had settled and dissipated, the plants were placed in a closed sedan delivery truck to protect them from contamination by subsequent tests. Glass slides were set out for flight 9.

In series 3, flights 13–15 in Table 1, the toxicant and oil and the manner of exposing potted pines and ribes to the fog were the same as for series 2. Two pines and eight ribes were used to sample each flight.

*Table 1.* Damage to *Ribes roezli* and *Pinus monticola* fogged with 2,4-D on May 8, 1950, by helicopter fogging unit. Pescadero, Calif. Final observations made on October 17, 1950. D=dead; d=per cent defoliated.

| Flight number | Ounces 2,4-D acid per acre | Feet above ground | M.P.H. | Two ribes under cover† | | | | White pine in open | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Heavy 20 ft W | Medium 10 ft W | Light 10 ft E | Open 20 ft E | 20 ft W | 10 ft W | 10 ft E | 20 ft E |
| 9 | 3 | 20 | 25 | d 100<br>d 75 | D<br>d 100 | D<br>D | d 100<br>d 75 | d 0 | d 0 | d 0 | d 0 |
| 10 | 6 | 20 | 20 | d 25<br>D | d 25<br>D | D<br>D | D<br>D | d 0 | d 0 | d 0 | d 5 |
| 11 | 9 | 20 | 15 | d 25<br>d 100 | d 75<br>D | D<br>d 100 | D<br>D | d 0 | d 0 | d 60 | D‡ |
| 12 | 12 | 20 | 10 | d 100<br>d 100 | d 100<br>D | D<br>D | D<br>D | D‡ | d 0 | d 0 | d 75 |
| 13 | 12 | 100 | 10 | D<br>D | D<br>D | D<br>d 25 | D<br>D | d 20 | —— | —— | d 0 |
| 14 | 9 | 100 | 15 | d 100<br>d 100 | d 90<br>d 50 | D<br>d 100 | d 100<br>d 100 | d 0 | —— | —— | D‡ |
| 15 | 12 Double run | 100 | 20 | d 25<br>d 100 | d 25<br>D | d 100<br>d 100 | d 25<br>d 25 | d 0 | —— | —— | d 50 |

†Feet and direction from center of test strip.
‡Died from causes other than chemical injury.

In series 4, flight 16, where about an acre of ground supporting coyote brush was fogged, an impressive blanket of fog was confined largely to draws and lower slopes. The fog tended to settle and accumulate in draws and depressions, and to be dissipated rapidly from high points along local ridges. The deposits of oil and toxicant on the foliage of ribes bushes and coyote brush just after the treatment were not large enough to be seen by the naked eye. The fog in this test did not restrict the visibility of the pilot when he flew across the slope starting from the bottom and working up. Unless

there was a rapid drift of the material out of the area, flagging or marking the swath for the pilot would not be necessary as the blanket of fog is visible and clearly defined. A certain amount of overlap could be calculated with an observer's help on the initial runs.

The first flight was made at 5:25 and the last one at 7:42 a.m. The morning was cool, overcast, and nearly windless – ideal conditions for fogging. The wind velocity was between 0 and 2 m.p.h. and the direction of air movement was generally down the draw towards the line of flight. The air temperature was about 49° F. and the relative humidity was close to saturation for the duration of the tests. The test strip was marked by two pieces of high-visibility cloth placed on the strip center at the beginning and end of the designated flight course. The estimated width of swath for all tests (series 1–4) was 60 feet.

The fogging equipment operated satisfactorily. As shown in Fig. 1, *B* and *C*, heavy twin columns of dense fog joined in one solid column about 20 feet back of the ship. In the preliminary flights with fogging oil alone, a large part of the fog appeared to settle evenly on the designated strip. Some, however, remained in the air for a time, drifted slowly down wind, and was visible for ¼ mile or more. Slower speeds were more effective in confining the fog to the test

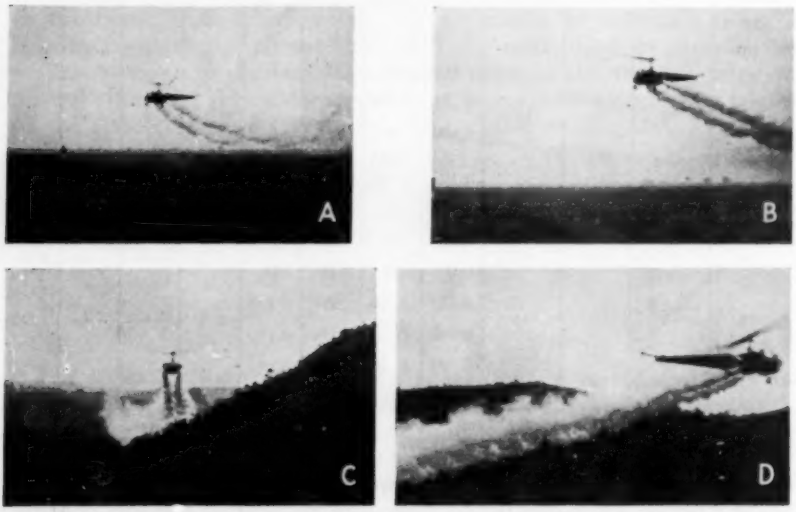


FIG. 1. *A*. Preliminary tests of the thermal fogging unit at Stockton, Calif., March 22, 1950. Air speed of helicopter 15 m.p.h. at height of 30 feet above ground. Wind velocity about 5 m.p.h. *B*. Same as *A* at an air speed of 25 m.p.h. *C*. Fogging 2,4-D in oil on ribes bushes and pine placed across a test strip at Pescadero, Calif., May 8, 1950. Air speed 15 m.p.h. Wind velocity less than 2 m.p.h. Thermal heads have been turned inboard from position used in *A* and *B* above. Note how the twin columns of fog form a continuous blanket about 20 feet behind ship in contrast to long twin columns shown in *B, D*. Same of *C* at an air speed of 25 m.p.h.

strip; yet at 25 feet and 25 m.p.h. the fog seemed to settle because of the rotor wash and to penetrate the brush satisfactorily. Between heights of 25 and 100 feet, deposition and control of the fog were governed by the speed of the ship. Even at 100 feet the fog was driven downward effectively when air speed of the helicopter was 15 m.p.h. or less.

The results of the fogging tests on potted ribes and white pine plants are summarized in Table 1. Damage from the 6-ounce application (flight 10) is illustrated in Fig. 2.

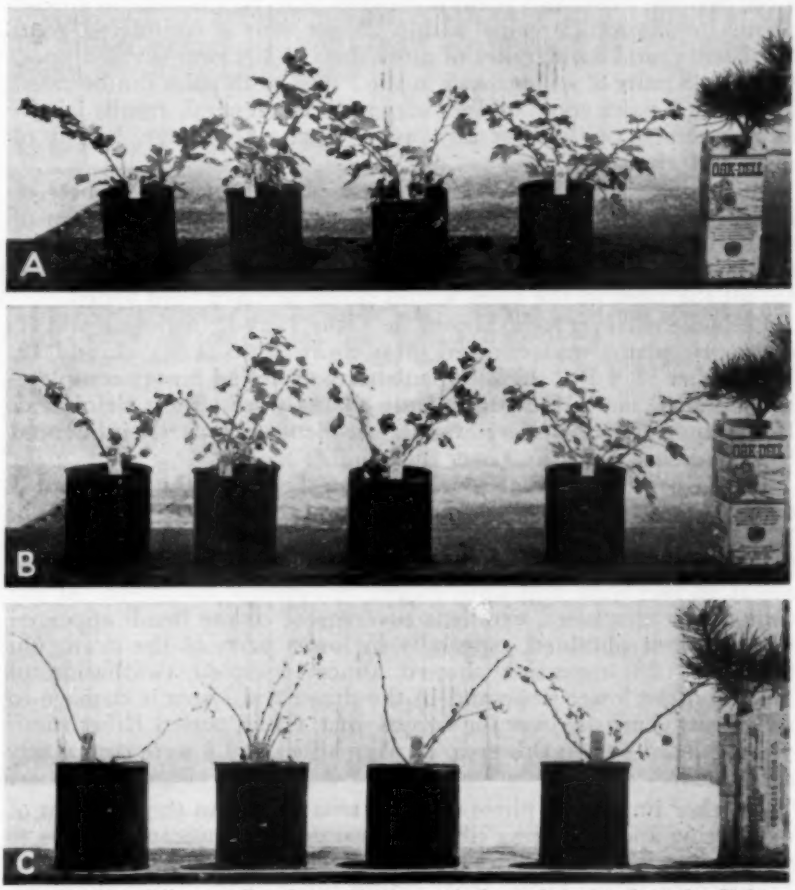


FIG. 2. Four *Ribes roezli* and one *Pinus monticola* used as test plants for flight 10. Fogged on May 8 at 6 ounces of 2,4-D acid equivalent per acre. *A*. Picture taken on May 19, when ribes foliage first showed discoloration. Ribes plants, left to right, were placed in open, light, medium, and heavy brush cover at time of fogging. *B*. Picture taken on June 1 when leaves of ribes placed in open, light, and medium cover showed earliest twisting and drying. *C*. Picture taken on July 15, when stem tips and all leaves of the four ribes plants were dead. No damage to pine for duration of test.

## RESULTS

The damage caused to test plants for flights 9–15, as shown in Table 1, is an indication of the efficiency of the equipment, because the plants were placed on a designated test strip. The pilot made only one pass over the course at the required speed and height. If a gust of wind or a momentary shift in wind direction occurred, he had little chance to compensate for the change.

From the standpoint of the consistency in results shown by duplicated ribes tests, and insofar as the purpose of the tests are concerned, a 100-per-cent defoliated plant is considered to be the same as a dead plant. Defoliation agreeing within 25 per cent is considered good consistency, and a difference of more than 25 per cent is rated poor. For the 28 pairs of *Ribes roezli* in the 7 flights, 18 pairs can be rated identical, 3 pairs good, and 7 pairs poor. In general, results are in fair agreement with those anticipated from the dosage, height of ship, and air speed.

Surprisingly effective defoliation was obtained with 3 ounces of acid per acre (flight 9). There was some decrease in effectiveness of the herbicide with increase of brush cover. Had it not been for poor coverage of the east side of the strip on two occasions (flights 9 and 15) all the ribes in the open would probably have been killed.

Besides the *Ribes roezli* shown in Table 1, 21 *R. petiolare* and *R. nevadense* plants were exposed (May 8) in flights 9, 10, 11, and 12. By October 17, 4 *R. petiolare* plants were dead and 5 were completely defoliated, and 12 *R. nevadense* plants were almost defoliated. Defoliation of *R. petiolare* and *R. nevadense* was partly influenced by greenhouse conditions over the summer months.

In the practical test of fogging coyote brush (flight 16) about 1 acre was treated from a height of 20 feet and at a speed of 20 m.p.h. The dosage per acre was about ¾ gallon of oil and 6 ounces of 2,4-D acid. There was some overlap of contiguous strips, which were about 40 feet wide and were fogged in opposite directions. At the time of the treatment, excellent coverage of coyote brush appeared to have been obtained, especially in lower parts of the draw. On September 23 inspection showed almost complete defoliation of plants on the lower slope and in the draw, and systemic damage to the plants generally over the fogged area. Of 15 potted *Ribes roezli* plants placed out on this area, 12 were killed and 3 were completely defoliated.

Another important phase of these tests relates to the problem of defoliating and damaging ribes without doing significant damage to white pines. The three pines that ultimately died (Table 1) gave every evidence of being killed from causes other than chemical injury. There was no significant damage to pines receiving the dosages of 3 or 6 ounces per acre on the regular test strip. Damage to growing points and loss of needles occurred on one pine in each of flights 11, 12, 13, and 15. On the basis of these tests it is believed that ribes sensitive to 2,4-D could be defoliated with low dosages of toxicant without causing significant damage to associated white pine. In the

case of seedling white pine or recently planted pine stock, fogging should probably be done late in July or in August, when the trees have completed the year's active growth and when ribes plants can still be damaged through defoliation.

For plant-suppression work the advantages of economy in weight and volume of materials used in fogging must be measured against the drift hazard and the difficulties of controlling the deposition of an effective residue. For deposit of an effective residue of a herbicide most of the droplets probably should have a diameter of 50 microns or more. The chemico-ecological suppression of ribes by sublethal dosgaes of 2,4-D applied by aircraft and by ground equipment will be further studied by field tests in the mixed-conifer type of the Sierra Nevada of California.

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## News from the North Central Conference

Many interesting items were sent in by Stahler before he left for his European trip. We are going to the printer later than planned so unfortunately most of his contributions are out of date. By the time this reaches you he will have returned from Europe and his offices will probably have been changed from Brookings, South Dakota to the University of Missouri, Columbia, Missouri.

***R. F. Fuelleman, University of Illinois***

Robert F. Fuelleman, 56, Professor of Agronomy, University of Illinois, died April 6, 1951 after having been ill a little more than a month with a heart ailment. Professor Fuelleman had been on the staff since 1937. He was interested primarily in forage crops, but had been active on the weed project since 1942.

Dr. Fuelleman received his bachelor's, master's, and doctorate from the University of Wisconsin.

***T. F. Yost, Kansas State Board of Agriculture***

A great friend of Kansas agriculture passed from the scene, January 16, when T. F. Yost, State Weed Supervisor for the Kansas State Board of Agriculture, succumbed to a heart ailment at a Topeka hospital.

Roy Freeland, Secretary of the Board, praised Yost's record of valuable service to Kansas farm people. "He devoted time and effort far beyond the call of duty," Freeland stated. "His enthusiasm and his ability will be seriously missed by county and state officials, commercial groups and agricultural people associated with him over a long period of time. It will be most difficult to fill his place on the staff of the Board of Agriculture."

Born in Harvard, Nebraska, Yost moved to Rush county, Kansas in 1900, where he attended grade and high school, going on to graduate in agriculture from Kansas State College. After serving with the army during World War I, Yost became a county agent and worked in several counties in Kansas.

In 1937 when the State Legislature passed a Noxious Weed Law and created a Noxious Weed Division, the Board of Agriculture appointed Yost as its director. Through the years the Division, under Yost's capable leadership, expanded in importance to the farm people of the state and became a model that was used by many states in building their own weed departments.

Upon his death at 56, Yost is survived by his wife, Sara, three children, Hallam T. Yost, Topeka; Mary E. Yost, Kansas City and Frances Yost, Miami, Florida, and four sisters and six brothers.

[Subscription number one to "Weeds" was issued to Mr. Yost at Milwaukee in December 1950]

## News from the Western Weed Control Conference

Dr. W. W. Robbins, Head of the Division of Botany of the California Agricultural Experiment Station retired July 1, 1951 after 29 years of service with that institution. Dr. Robbins is now President of the Western Weed Control Conference. He has long been active in the field of weed control research and is author and co-author of many articles, bulletins, and books on the subject. Most noteable of these are "Weed Control" by Robbins, Crafts and Raynor and "Weeds of California" by Robbins, Bellue, and Ball. Dr. Robbins spent six months in South America in 1948 as a weed control lecturer and consultant on a mission for the U. S. Office of Agricultural Foreign Relations.

Mr. Luther G. Jones who is alfalfa research specialist in the Agronomy Department of the California Agricultural Experiment Station served as the expert on agronomy on the Economic Survey Mission of the International Bank for Reconstruction and Development to Iraq from February 12 to June 20, 1951. This mission is in cooperation with FAO of the United Nations. Mr. Jones has done considerable research on the control of weeds in alfalfa and is chairman of the Western Weed Control Conference committee on control of annual weeds in legume crops.

Robert L. Warden who is Extension Weed Specialist in Montana reports that 56 colonies of *Chrysolina gemellata* beetles were introduced from California to goatweed *(Hypericum perforatum)* infestations in western Montana during the middle of May 1951. This large scale liberation was made possible by the cooperation of the U. S. Bureau of Entomology and Plant Quarantine, the Montana State Entomologist, the Extension Service, the U. S. Forest Service, and the Western Montana Weed Committee. These introductions of beetles were made in the major goatweed infested areas in six Western Montana counties.

Georg Jacobson who is in charge of local weed control experiments on farms for the National Agronomy Experiment Station at Uppsala, Sweden spent May and June in the United States during which time he visited a considerable number of state experiment stations and research laboratories of manufacturers of herbicides. His first stops were made at the Iowa and Utah Stations. When he was at Logan, Utah on May 22 he had definite plans for visiting the experiment stations in California, South Dakota, North Dakota, Minnesota, Wisconsin and Michigan, the U. S. Division of Weed Investigations

at Beltsville, Maryland, Dow Chemical Company research laboratories in California and Michigan, Shell Oil Company Laboratory at Modesto, California, and the DuPont Laboratories at Wilmington, Delaware.

By F. L. TIMMONS, Utah

The Western Washington Pea Growers near Mount Vernon, Washington have appropriated to the Northwest Washington Experiment Station at Mount Vernon sufficient funds to carry on a weed research program at that station for the next two years. Mr. Dwight Peabody who obtained M.S. degree from Washington State College in June 1951 has been appointed to the position to conduct the weed research at the Northwest Washington Experiment Station. Mr. Peabody did his undergraduate work at Ohio State University and during the past two years has been working under the direction of Dr. L. W. Rasmussen at Washington State College on a study of the physiologic and histiologic changes in the roots of Canada thistle induced by spray applications of 2,4-D to the vegetative portion.

By L. W. RASMUSSEN

### *New Legislation in Idaho*

Idaho launched the other half of a complete weed program when a new seed law and several new sections of weed legislation passed by the last session of the Idaho Legislature became effective.

The new seed law is based on the Uniform State Seed Act. More up-to-date and workable than the old law, enforcement is removed from the University of Idaho Experiment Station and placed in the State Department of Agriculture. Changes in the noxious weed list may be made by the Commissioner of Agriculture after a proper hearing. Clearly defined prohibitions and labeling requirements make the law much clearer than previously. The new seed act was reviewed and approved by farm organizations, seedsmens' associations, Federal Seed Law representatives, Crop Improvement Association officials and state agricultural officials.

Control over weed spread through traffic in feed, forage, fertilizer, and machinery is provided for in the new weed legislation. The commissioner of Agriculture in cooperation with the Board of County Commissioners may establish lists of noxious weeds for this purpose. Traffic in these materials containing the designated noxious weed seeds is a violation of the law. Sections of this Act were patterned after the Kansas Law.

The new weed legislation became effective in May; the new seed law on July 1.

By GENE WHITMAN, Idaho

## Conference Meeting Dates

*The Western weed control conference* will meet at the Mapes Hotel, Reno, Nevada, February 5, 6 and 7, 1952. According to Sec'y-treas. Walt Ball, one of the three days will be devoted to research. Papers include such widely diverse subjects as ecology, weeds in irrigation waters, soil sterilants, and brush. Additional features of the program deal with the regulatory and educational aspects of weed control.

*The Northcentral weed control conference* will convene in Oklahoma City, December 11, 12 and 13, 1951 at the Biltmore Hotel. The program has much to offer all lines of interest in weed control. Sectional groups representing Industrial, Regulatory, Extension, Horticultural and Engineering interests will meet the afternoon of December 11th. As is customary, the Research Committee will meet all day on the 10th. Other highlights will be sessions on the control of grasses and brush, and a panel on pasture weeding. The last day will emphasize the broader implications of weed control with regulation, public relation, plant poisoning, etc. being on the agenda.

*The Northeastern weed control conference* is continuing its policy of meeting at the Hotel New Yorker the first week in January. The dates this year are 1, 2, 3 and 4. Although the program is not yet completed, it is likely that the past year's outline will be followed. The directors and committeemen will meet the afternoon and evening of the first day. General papers will be heard on the second and detailed research papers on the third. The highlight of the conference will be the open meeting of the Research Coordinating Committee scheduled for the entire last day of the conference. This session is where much of the actual record of the conference is accomplished. For a detailed program, be sure your name is on the mailing list of the Sec'y-treas., W. C. Jacob, Long Island Vegetable Research Farm, Riverhead, Long Island.

*The Southern weed control conference* plans to meet for two and one half days at the Atlanta Biltmore, Atlanta, Ga., immediately following the Association of Southern Agricultural Workers. According to preliminary plans sent us by President Shear, the weed conference will get under way the afternoon of February 6th and continue through the 8th. Mr. B. B. Jones, Sec'y of the A.S.A.W. is handling local arrangements.

# BIBLIOGRAPHY OF WEED INVESTIGATIONS

## for

## January, February, and March

## 1951

Prepared By
*Division of Weed Investigations,*
*Bureau of Plant Industry, Soils, and Agricultural Engineering,*
*Agricultural Research Administration,*
*United States Department of Agriculture*

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Division of Weed Investigations does not assume responsibility for the subject matter cited.

The Federal Division of Weed Investigations is servicing the section on bibliography. This is a further attempt to have under one cover as much information as possible concerning weeds. Due to overlapping in publication dates two, three-month contributions are being printed in this first issue. In succeeding issues, however, only one section will be included.

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